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ON THE MECHANICAL PROPERTIES OF MATERIALS OF CONSTRUCTION, AND ON VARIOUS PREVIOUSLY UNOBSERVED PHENOMENA, NOTICED DURING EXPERIMENTAL RESEARCHES WITH A NEW TESTING MACHINE, WITH AUTOGRAPHIC REGISTRY.*

By Prof. R. H. THURSTON.

SECTION II.

14. *Introductory.* — The preceding section has been devoted to a description of the peculiar form of testing machine employed by the writer during these researches, to an account of the general method of obtaining from any material an autographic record of its mechanical properties, and to the interpretation of strain diagrams thus obtained from the useful metals and other materials of construction.

The part here presented contains an account of some of the more interesting and fruitful of the special investigations conducted with the apparatus, and embodies a description of certain remarkable and hitherto unobserved phenomena accompanying the distortion of metals, the discovery of which must affect the theory of the effect of stress in producing strain, and, consequently, must somewhat modify engineering practice.

15. *General Deductions.* — From what has already been shown, we may deduce the following *resumé* of methods of determining the several more important properties of materials by an inspection of their strain diagrams.

1. *To Determine the Homogeneousness of the Material.*—Examine the form of the initial portion of the diagram between the starting point and the sudden change of direction which has been shown to indicate the elastic limit. Notice also its inclination from the vertical and compare with it the inclination of the "elasticity line."

A perfectly straight line beneath the elastic limit, perfectly parallel with the "elasticity line," shows the material to be *homogeneous as to strain; i. e.*, to be free from internal strains, such as are produced by irregular and rapid cooling or by working too cold. Any variation from this line indicates the existence, and measures the amount, of strain. A line considerably curved as in No. 6, Plate I., exhibits the existence of such strain.

Next, examine the form of the curve immediately after passing the elastic limit. A line rising from the elastic limit, regularly and smoothly, approximately parabolic in form and concave toward the base line, as in No. 22, indicates *homogeneousness in structure*, and the absence of such imperfections as are produced in wrought-iron

*Transactions of American Society of Civil Engineers.

by cinder, or in cast metals which have been worked from ingots, by porosity of the ingot.

A line turning the corner sharply, when passing the elastic limit, and then running nearly or quite horizontal, as in other irons, and in the low steel of Plates II. and III., or actually becoming convex toward the base line, as with some of the woods in Plate I., and then, after a time, resuming upward movement by taking its proper parabolic path, indicates a decided want of this kind of homogeneity. The relative length of the depressed portion of the line, and the amount of depression, measures the relative defectiveness of materials compared in this respect.

Finally, compare the diagrams produced by several specimens of the same kind of material or from the same mass. Homogeneousness in general character and *homogeneousness in composition* are proven by the precise similarity of these diagrams, while a greater or less variation of the curves compared, indicates a greater or less difference in the specimens of which they are the autographs.

Materials should usually exhibit great homogeneousness in all these three ways, to be perfectly reliable. Perfect homogeneousness is nottobe expected in either respect.

2. *To Determine the Elastic Resistance of the Specimen.*—Measure the height of the curve at the elastic limit, using the scale of torsion, or for tension, which is given for each machine and for each standard size of test-piece, as shown in the accompanying plates.

3. *To Determine the Resistance offered to any given amount of Extension, or that producing a given set.*—Measure the ordinate of the curve at the point whose abscissa, or distance from the origin, measures the assumed degree of set.

4. *To Determine the Ultimate Resistance of the Material.*—Measure in a similar manner the maximum ordinate of the curve.

5. *To Determine the Resilience of the Piece within the Elastic Limit* (*i. e.*, the work required to produce an evident and permanent set, approximately proportional in amount to the degree of change of form of the specimen; this quantity measures the power of the material to resist blows, and its determination is evidently quite as important as that of resistance to static stress, which latter forms one of the factors of the former).—Measure the area comprised between the ordinate of the curve at the elastic limit and the initial part of the curve; this quantity is proportional to the required value. Or multiply the elastic resistance of the material by the extension within the elastic limit. As an approximate result, two-thirds this product is the quantity required in inch-pounds or foot-pounds, according as measures of extension are taken in inches or feet.

6. *To Determine the Resilience of the Material within any Assumed Limit of Extension* (*i. e.*, the magnitude of blow required to produce a given set).—Measure the area of the curve up to the assumed limit, as, for example, the area in Plate III., under No. 21, Z, 21, 21, Y, x, where the assumed set is the extension from Z to x. Two-thirds the product of the resistance measured by the altitude Yx, and the extension bx, gives, as before, an approximate value for ordinary purposes.

7. *To Determine the Total Resilience or Shock-Resisting Power of the Material.*—Measure the total area of the diagram. For ductile materials an approximate value is obtained by taking two-thirds the product of the maximum tenacity by the maximum extension. For hard and very brittle materials one-half the same product gives very accurately its values. For intermediate qualities the true value is more nearly two-thirds this product, also Swedish wrought-iron, white cast-iron, and hardened steel illustrate the first and the second classes; ordinary tool steels are examples of the third class, as is also iron like No. 22.

8. *To Determine the Effect of a Load given in pounds per square inch of stress.*—Find a point in the curve having an ordinate which measures the given stress. The abscissa of that point measures the extension under that load. In other words, a point being found in the curve, the height of which above the base line is equal to the load per square inch, its distance from the origin measures the extension of the material as produced by that stress.

9. *To Determine the Effect of a Blow or a Shock, whose measure is given in inch-pounds of energy* (*i. e.*, of which the work that it is capable of doing is known).—Find a point on the curve whose ordinate cuts off an area between itself and the origin, representing the given amount of work. Or find such a point that two-thirds

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the product of the stress measured by its ordinate, and the extension corresponding to its abscissa, is equal to the number of inch-pounds given. The position of this point shows the maximum strain and the maximum extension of the material under the assumed conditions. Drawing a line through this point parallel to the nearest "elasticity line," the distance of the point at which it intersects the base line from the origin indicates the resulting set.

10. *To Determine the Effect of a Blow upon the Material, when already strained by a dead load.*—Determine first the extension produced by the application of the static stress, as in 8, and then find that point on the curve between the ordinate of which and the ordinate of the point indicating the strain just found as due the dead load, an area is intercepted which measures the work done by, or the energy of, the shock which has been assumed or calculated.

15. EXAMPLES.—Illustrations of the first seven of the above-described processes are either given in the preceding portions of this paper or will be noticed hereafter, during the progress of special researches. Those succeeding may be illustrated thus:

(1.) Given, a load of 30,000 lbs. per square inch. Determine its effect upon good qualities of cast and wrought iron, low steels, tool steel, and the weaker metals.

Referring to Plate II. for examples, we find that neither cast copper, lead, tin, nor zinc would sustain such strain; all would be broken.

Good irons, Nos. 1 and 6, would be strained beyond their limits of elasticity, and would take a set after an extension of about 1 and 1¼ per cent, respectively. The exceptional iron, No. 22, would be strained to a point which is so nearly its elastic limit that it would remain practically uninjured.

The low steels, Nos. 69, 67, 76, would bear the stress with a similar degree of safety, very nearly. The first would have a considerable margin of safety within its elastic limit; No. 67 would be nearly, and No. 76 would be quite, strained to the elastic limit, while No. 98 would take a set of about one-fifth of one per cent.

If the strain were torsional, the weaker metals would be twisted off by a force corresponding to that here assumed, the good irons would take a set of about 25 deg., the best iron and the three stronger steels would take no appreciable set, and the softest of the latter would set at about 10 deg. In these cases the specimens are supposed of standard size. For other sizes the forces producing similar effects would vary as the cubes of the diameters.

(2.) Given, the magnitude of a shock, or blow, *e. g.* as equal to that due a weight of one ton, 2,000 pounds, falling one foot, the rod taking the strain being of one sq. in. area of section and one ft. long. Determine the effect for each of the above-named materials.

The effect of this blow is equivalent to an expenditure of energy amounting to $2{,}000 \times 12 = 24{,}000$ inch-pounds.

The weaker materials, not possessing an ultimate resilience of this amount, would be broken.

Forged copper would be strained and would take a set after very nearly 12½ per cent. of extension, since

$$0.12\tfrac{1}{2} \times 12 \times \frac{24{,}000 \times 2}{3} = 24{,}000$$

the work done by the blow being equilibriated by the product of two-thirds the resistance, noted at 110 deg., Plate II., into the extension. Perfect accuracy of figures may be insured by perfectly accurate measurements.

The specimen of iron No. 1 would be given an extension and set of nearly 0.068, since the resistance, under this amount of stretch, would be approximately 45,000 pounds per square inch, and the work during extension would be

$$0.068 \times 12 \times \frac{45{,}000 \times 2}{3} = 24{,}000 \text{ inch-pounds.}$$

The iron of special grade No. 22 would be elongated $0.058 = 0.69$ inch, as

$$0.069 \times 12 \times \frac{52{,}000 \times 2}{3} = 24{,}000 \text{ nearly.}$$

The same blow would produce on the rod, if made of such steel as No. 69, an extension of $0.0384 \times 12 = 0.461$ inches, estimated thus,

$$+\tfrac{1}{3} = 24{,}000 \div \tfrac{2}{3}\ 78{,}000 = 0.461,$$

it being found by "trial and error," that the extension 0.0384 develops a maximum resistance of 78,500 pounds per sq. in.

It is evident that, where extreme accuracy is required, the curves should be transferred to a new scale in which the abscissas should be a scale of elongation instead of angular distortion, and the area should be

carefully measured.* For the latter work an Amsler "Planimeter"† is useful.

(3.) Given, a bolt of dimensions as last assumed, strained with the effect of a load of 30,000 lbs., as in example (1,) determine the effect of a blow of 24,000 inch-pounds energy, occurring while the bar is sustaining the static load.

The effect of the dead load, as already calculated, is to produce a strain upon the low steels, and upon iron like No. 22, which would keep them extended only a very minute fraction of their original length, this extension being, even with the latter material, but 0.05 of one per cent. The effect of the blow would be, practically, the same as has just been estimated for the unloaded bar.

Nos. 1 and 6 would be, as already shown, extended 1 and 1½ per cent. respectively, by the simple load. The added effect of the blow would be to produce an additional extension and set of 0.0533 and 0.0555 respectively, since the mean resistance, during this extension, is

$$\frac{45,000 + 35,000}{2} \text{ and } \frac{42,000 + 30,000}{2}$$

respectively, and the extension must be,

$$24,000 \div \frac{45,000 + 30,000}{2} \div 12 = 0.0533 \text{ and}$$

$$24,000 \div \frac{42,000 + 30\,000}{2} \div 12 = 0\,0555$$

The bar is stretched in the first case 0.64 inch; in the second 0.666 inch, by the blow, if made of such iron as that of specimens Nos. 1 and 6.

It should be remarked here, that although the diagrams obtained from the various materials tested, give data from which to estimate their relative value in resisting shock, the absolute results of calculation, with no modification for varying rapidity of action, will be but approximate.

This is a consequence of the facts that the inertia of the body struck will effect the result, and that the actual resistance varies with the velocity of rupture. A rod which will sustain safely the blow of a heavy body, would yield readily under a blow of similar energy struck by a light weight moving with proportionally increased velocity. The mathematical investigation of this effect, which has not hitherto been noticed, remains to be given. It is only necessary to state here, that a rod of uniform section, and homogeneous in structure, will be uniformly extended by a force slowly applied. A blow received at one end will extend it most at the portion nearest that end, and the more rapid the blow the more is its effect concentrated. It is possible to produce actual fracture at one end by a very rapid blow, and for rupture to become complete before the shock is felt at the opposite end. This action is seen daily in every workshop where pieces are broken from heavy masses by the blow of a hammer.

The effect of a blow depends, therefore, not only on the magnitude of that product of mass into height due its velocity, which we call *vis viva*, but also upon the magnitude of the factors. It further follows that of two materials having equal tenacity and equal ductility, the one having greatest density will be most liable to fracture by impact.* This inference is confirmed by experience.

In general, a rod should be somewhat larger at the end receiving the shock, and this enlargement should be greater as the blow is more rapid. Conversely, blows of equal energy are the most injurious when given by bodies of light weight moving at high speed. This difference is exaggerated by any cause which increases the density of the material. The variation of resistance with the rapidity of rupture will be considered more at length hereafter.

It is readily seen that we have here an explanation of the fact, that fracture produced by a quick blow is granular in character, while a steady pull brings out the "fibrous" texture of iron. In the former case the action is concentrated upon a cross section close to the point at which the blow is received; in the latter instance inertia acts less effectively in resisting the transmission of the rupturing force to other portions of the piece, and the drawing out process is permitted to take place.

16. *Peculiar Problems* sometimes present themselves in practice which cannot be solved by any published methods—why, it is difficult to say, but partly, it is probable, because of a deficiency of experimental data, and partly because known authorities have not been led by actual experience in

* See London "Engineer," Nov. 8th, 1872.

† It is evident that diagrams accurately representing tests made with the common testing machine afford similar facilities for solving these problems.

* "Mechanics' Mag.", Dec., 1871, p. 492.

engineering practice to perceive the importance of their applications.

Of these the following is an example:

To determine the effect of a succession of stresses, whether static or dynamic, each of which strains the material beyond the original or the acquired limit of elasticity.—An illustration of this action is given by the repeated bending, stretching, or other form of distortion by external force, of any material producing at each application a new set. The same case is illustrated by the gradual elongation of a rod by repeated blows, the energy of each of which exceeds the elastic resilience of the material.

Determine the elastic resilience of the material existing previous to the application of each stress, by taking the area comprised between two lines drawn through that point on the curve of the material chosen, whose abscissa represents the existing extension, one of which lines is an ordinate and the other of which is parallel to the nearest "elasticity line." This area represents the elastic resilience of the piece; *i. e.*, a blow having an equivalent energy would leave the piece uninjured and without set. Deducting this amount from the energy of the given blow, the remainder of the work done by that blow is expended in producing set or extension, and may be determined as already described.

The effect of a simple force may be determined by deducting from the total distortion produced by each application of that force, the elastic range of the material.

It is thus readily ascertained, in either case, how much each application will add to the set, and how many applications will be required to produce rupture. It is here assumed that distortion within the elastic limit leaves the piece uninjured, however often it may be repeated. This assumption seems correct, *a priori*, and is well sustained by the valuable researches of Wohler* and others.†

The effect of repeated bending, or other form of strain, can thus be inferred from an examination of the strain diagram of the material, obtaining from a single experiment a determination hitherto only obtained by a long and tedious process of repeated distortion. Such investigations of the "fatigue" of metals are often of great importance.

17. *The effect of Time on Metals left under Strain.*—The effect of stress is modified when metals are left under strain for considerable intervals of time. It had generally been supposed that this effect was to weaken the resistance whenever the material was left exposed to a strain exceeding the elastic limit.

This idea seems sustained by the experiments of M. Vicat, made at Paris about forty years ago.* He states that four wires were extended, respectively, by $\frac{1}{4}$, $\frac{1}{3}$, $\frac{1}{2}$, and $\frac{3}{4}$ their ultimate resistance, and their elongations were observed and recorded at intervals of one year. The relative extensions observed indicated a gradual lengthening of the three which were strained beyond the elastic limit, and that most strained finally broke after sustaining $\frac{3}{4}$ its original ultimate breaking weight two years and nine months, the point of rupture being finally determined by the action of corrosion which had not been entirely prevented.

The several extensions were as follows:

No. 1,	sustaining	$\frac{1}{4}$,	33 months	0.000	per cent.
No. 2,	"	$\frac{1}{3}$,	" "	0.275	"
No. 3,	"	$\frac{1}{2}$,	" "	0.409	"
No. 4,	"	$\frac{3}{4}$,	" "	0.613	"

The rate of extension was nearly proportional to the times, and the total extension to the forces. M. Vicat concludes that metal thus overstrained will ultimately break, and his paper has caused much uneasiness among members of the profession, as indicating a possibility of the ultimate failure of structures having originally an ample factor of safety.

The elegant and valuable researches, also, of H. Tresca, on the flow of solids,† and the illustrations of this action almost daily noticed by every engineer, seem to lend confirmation to the supposition of Vicat.

The experimental researches of Prof. Joseph Henry, on the viscosity of materials, and which proved the possibility of the coexistence of strong cohesive forces with great fluidity,‡ long ago proved, also, the possibility of a behavior in solids, under the action of great force, analogous to that noted in more fluid substances.

* Zeitschrift fur Bauwesen Festigkeitversuche mit Eisen und Stahl," Berlin; also Lond., 1860. "Engineering." 1871.

† Fairbairn: "Civil Engineer and Architect's Journal," Vols. XXIII., XXIV.

* "Annales de Chimie et de Physique," 1834; Tome 54, p. 35.

† "Sur l'Ecoulement des corps solides;" Paris, 1869-72.

‡ "Proc. Am. Phil. Society," 1844.

On the other hand, the researches of the writer, as described in the first section of this paper, indicating by the form of strain diagrams, that the progress of this flow was accompanied by increasing resistance, and the corroboratory evidence furnished by all carefully made experiments on tensile resistance, as those of King and Rodman, Kirkaldy and Styffe, made it appear extremely doubtful whether materials were really weakened by a continuance of any stress, not originally capable of producing incipient rupture.

18. To determine this point, a series of experiments were made, the general result of which was first formally announced in a note to this Society,* in which the first experiment, commenced during the session of the National Academy of Science at the Stevens Institute of Technology, was described, and in which the first deductions, since slightly modified by an extended investigation, were given. In Plate III., No. 16, is a *fac simile* of the strain diagram obtained at the first experiment.

A piece of iron, of a good quality of metal, but badly worked, as shown in the sketch already given in Section 1, was placed in the machine and strained considerably beyond its elastic limit. It was then left 24 hours under the strain thus produced at *A*, Plate III. At the end of this period, the pencil was found precisely as it was left, and not the slightest evidence of yielding was noted. The slight depression observed in many examples to be given, is produced by a slight compression of the wood used in blocking the machine at the beginning of the interval. No evidence of flow was therefore obtained.

Upon attempting to produce further change of form, however, the unexpected discovery was made that the test-piece had acquired an increased resisting power. The pencil, instead of following the general direction taken the day previous, rose, as seen in the diagram, until a resistance was indicated, *exceeding by nearly 30 per cent.* that shown before the specimen was left under strain. This resistance having been overcome, the piece yielded with a slightly decreasing resistance, and, after considerable additional distortion, was left at *B* 24 hours. The result of the second experiment is seen to be an increase of nearly 15 per cent., and a third trial at *C* gave a small, but still perceptible, gain also.

This singular phenomenon appeared so remarkable and so important that experiments were continued upon various grades of iron, and upon other metals, the greatest care being taken to avoid any possible source of error. Several strain diagrams are given illustrating some of these experiments.

No. 10 represents that of a piece of good iron which is far more homogeneous and better worked than No. 16.

No. 68 is a piece of "Siemens-Martin steel" which was left under strain, at *A*, 24 hours, and at *B* an equal length of time. In the latter case, the applied force was wholly removed, at the end of 24 hours, before an attempt was made to produce further change of form. On renewing the strain the resistance is seen to have acquired an increased intensity very nearly absolutely equal to that shown at *A*, and relatively greater, a fact which will be found to aid in the determination of the real character of the phenomenon. A third experiment at *C*, shows a repetition of this action, and a fourth, similar to that at *B*, in all except time—for in the last experiment the time was but a fraction of an hour—gave a similar result. In each case it is noticeable that a slight fall from the maximum attained, follows the yielding of the test-piece.

No. 33, malleable cast iron, No. 52, double shear steel, and No. 81, tool steel, all exhibit this same stiffening under prolonged strain.

No. 17, "homogeneous chrome iron," was subjected to experiment four times. At *A*, the effect is very marked, and the resistance to further change of shape continues to increase slowly until left at *B* for a second trial. The maximum attained at *B* is not sustained, as further distortion occurs, and, after a slight decrease, the specimen was again left, the pencil resting at *C*.

Next day, the increase of resistance was found less considerable than at the previous experiment, and the line, after passing a maximum a few degrees beyond, falls quite rapidly. Fearing that the metal was about to rupture completely, it was left once more at *D*, another day, after which time its behavior was similar to that on earlier trials. It fully regains the maximum power of resistance noted after the trial at *C*, and, before rupture, it even slightly exceeds it.

* "See Trans. Am. Soc. C. E." Nov. 1873; "Journal Franklin Institute," March, 1874.

The hardest material experimented upon was the very hard chrome steel, No. 21. Left at *A* three days, the resistance at that degree of distortion was increased about 8 per cent., and, again at *B*, four days under strain gave a rise of nearly 4 per cent., after which a considerable rise occurred, in the ordinary manner, before rupture took place.

An interesting experiment was made with the best Swedish iron, a metal of such wonderful purity and ductility that one specimen, of standard size, was twisted nearly 600 deg. before completely breaking off.

No. 101, Plate III., is the strain diagram of the specimen tested for the purpose of determining the effect of continued stress. Here, as seems frequently the case, a loss of ductility apparently accompanies the increase of resistance and the total resilience appears to be comparatively slightly altered.

This specimen was strained until the limit of elasticity was just passed, and was then left at *A* one day. The result, with even the slight distortion of but 6 deg., producing an extension of a very minute amount, is similar to that before noticed, and the behavior here exhibited probably gives a clue to the causes of this peculiar action. After this trial, several others were made, and the metal is seen to have behaved in a manner precisely similar to the other grades of iron.

19. Reviewing all of the large number of experiments made since the discovery of this effect of continued strain, carefully comparing the curves obtained with each other, and with the diagrams obtained in the ordinary way, and, finally, making a comparison of the conclusions drawn from this research, with the results of the experimental work of other investigators, the writer has been led to the following, as the most probable explanation of this singular molecular phenomenon.

These strain diagrams are the *loci* of the successive limits of elasticity of metal, at successive positions of set.

The phenomenon here discovered is an elevation of the limit of elasticity by a continued strain. The cause is probably a gradual release of internal strain, occurring in a somewhat similar manner to that observed previously in cast iron in large masses, and less frequently, and generally in a less marked degree, in wrought-iron and other metals, which have been worked in large pieces, and in which such strain has been more or less reduced by a period of rest.* This loss of strength in large masses of wrought iron is stated, by Mallet, to amount frequently to one-half.†

20. The manner in which this reduction of internal strain occurs, by continued stress at the limit of elasticity, as here observed, may be readily conceived.

When the metal is thus strained, many sets of molecules are placed in positions in which they exert a maximum effect tending to produce molecular changes which may equalize the originally irregular distribution of inter-molecular stresses. After a time, the change actually takes place by "flow," and the resisting power of the piece becomes increased, and its limit of elasticity raised, simply because its forces are now no longer divided, and may act together in resisting external forces. The diagram itself exhibits the best evidence of the occurrence of flow, but it is also shown by an inspection of the broken specimen, as in Figures 6, 7, and 11, of Section I.

It was at first suspected that an action had been detected in this phenomenon, similar to that by which the "portative force" of a magnet is increased by loading its keeper more and more heavily until it becomes "supersaturated." It is not impossible, perhaps not improbable, that the two cases are similar in some respects, this behavior of the cohesive force in the present example, aiding to produce the extraordinary increase of resisting power here observed.

A comparison of the ductility registered by samples variously treated lends some confirmation to the supposition, formerly expressed, that, in all cases, the resilience does not increase in the same proportion as the increase of mean resistance, as a consequence of sustained stress, and this, if a a fact, may possibly be considered as corroborating the idea just suggested.‡

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* Compare London "Iron," Stability of Iron Structures; Feb. 1874; Van Nostrand's Magazine, April, 1874.

† "On the Co-efficients of Elasticity and Rupture in Wrought Iron in Relation to the Volume of the Mass, its metallurgic Treatment and the axial Direction of the constituent Crystals."—*Proc Inst., C. E.*

‡ Since the above was written, the "Journal of the Franklin Institute" has, in the issue for March, 1874, given an account of experiments made by Commander Beardslee, U.S N., during which metal strained beyond the elastic limit by tension, exhibited a gain of resistance at a position of earliest set, *i.e.*, an elevation of the elastic limit, from 23,075 to 26,100 pounds per square inch, 13 1 per cent., in seventeen hours. The material was bloom iron turned approximately to one-half square inch section.

A very important fact noted by the experimenter is that an

The discovery of this elevation of the elastic limit in all metals examined is also probably confirmatory of this idea.

If the explanation, just offered, of the apparent strengthening action of prolonged stress is correct, the conclusions of Vicat are not overthrown, although evidently not fully justified by his own experiments, and although the intervening forty years of engineering practice have not produced evidence which may be considered as confirmatory of them.

The same molecular movement, or flow, which rearranges the internal forces and relieves internal strain, may be a phase of that viscosity which Vicat supposed might in time permit rupture of metal, subjected to stress nearly approaching its original ultimate resistance, the one action being a more immediate result than the other, and the latter producing its effect, even when cohesive force may have been actually intensified.

Should this prove to be the fact, it would seem allowable to conclude that the forces of polarity and cohesion are not identical. The cause of the apparent increase of strength of iron, with increase of temperature, is seen to be explained by this relief of internal strain, which occurs most readily at high temperatures.

The experiments of the writer have not indicated the possibility of continued flow, and, consequently of ultimate rupture, except under stress, increasing in intensity up to the full maximum resistance of the material.* They no not, therefore, confirm Vicat's deductions, and the inference would seem, on the contrary, to be—that structures of metal do not become weakened with age, except as injury occurs by corrosion, or by overloading. The experiments of Roebling † and his opinion, as expressed in his report on the Niagara Suspension Bridge, are apparently correct.

Kirkaldy, also, concludes that the additional time occupied in testing certain specimens of which he determined the elongation "had no injurious effect in lessening the amount of breaking strain."‡ An examination of his tables shows those bars which were longest under strain to have had highest average resistance.

21. Wertheim supposed that greater resistance was offered to rapidly, than to slowly, produced rupture; Kirkaldy concludes that the contrary is the case. Redtenbacher § and Weisbach ‖ assume the law of resistance to be the same beyond the limit of elasticity as within it, and deduce formulas for resistance to shock which are widely inaccurate.

The experiments of the writer prove that, as had already been indicated by Kirkaldy (whose results, however, had been looked on by many of the profession with some suspicion), a lower resistance is offered as the stress is more rapidly applied. This conspires with *vis viva* to produce rupture.

This is seen at *w*, No. 101, Plate III., where a sudden increase of velocity produced a depression of the line, at the angle 110 deg., and it is exhibited in a much more marked degree in No. 118.

In the latter example, the strain was gradually applied until the point *a* was reached, when, with a suddenly applied force, a motion estimated at about one-tenth of a foot per second, was obtained, and, immediately at *b*, the resistance fell off very considerably, the pencil dropping to *c*. Again resuming the slowest movement, about one hundreth of a foot or less per second, resistance rose again to *d*. A repetition of the rapid movement between *b* and b^1, was followed by a loss of resistance again from b^1 to c^1, and, as is seen by the diagram, this occurred whenever the experiment was repeated. At *k*, distortion by a very slow movement was resumed, and continued until the specimen broke. Here we have, probably, the first direct determination of this question, in which the effect of *vis viva* does not appear.

We may therefore conclude that the rapidity of action, in cases of shock, and where materials sustain live loads, is a very important element in the determination of their resisting power, not only for the reason given already in paragraph 3 of this section, but because *the more rapidly the metal is ruptured, the less is its resistance*

apparent positive action was observed in the metal under strain by which the scale beam was actually thrown up by a force measuring 125 pounds. If this observation is not erroneous, or, if the action was not due to some accidental circumstance, we may have here a measure of the *intensifying effect* above described.

Commander Beardslee has communicated to the writer the experimental confirmation of the fact, deducible from the explanation here given, that this release of internal strain occurs to a nearly equal extent if the strained piece is simply laid aside for a similar interval after it has been given a set.

* Compare Kirkaldy—"Experiments on Wrought Iron and Steel"—pp 62–69; also see the plates given by Styffe, exhibiting curves for tension.

† "Journal Franklin Institute," 1860; Vol. XL., p. 360.

‡ "Experiments on Wrought Iron and Steel," pp 62, 83.

§ "Der Maschinenbau," Vol. 1

‖ "Mechanics on Engineering," etc.

to rupture. This loss of resistance is about 15 per cent.* in No. 118.

The cause of this action we may presume to bear a close relation to that operating to produce the opposite phenomenon of the elevation of the elastic limit by prolonged stress, and it may probably be simply another illustration of the effect of internal strain.

With a very slow distortion, the "flow" already described occurs, and but a small amount of internal strain may be produced, since, by the action noticed when left at rest, this strain relieves itself as rapidly as produced. A more rapid distortion produces internal strain more rapidly than relief can take place, and the more quickly it occurs, the less thoroughly can it be relieved, and the more is the total resistance of the piece reduced. Evidence confirmatory of this explanation is found in the fact that bodies most homogeneous as to strain exhibited the least of these effects.

It does not seem impossible that, at extremely high velocities, the most ductile substances may exhibit similar behavior, when fractured by shock, or by a suddenly applied force, to substances which are really comparatively brittle.

In the production of this effect, which has been frequently observed in the fracture of iron, although the cause has not been recognized, the inertia of the mass attacked and the actual depreciation of resisting power just observed, conspire to produce results which would seem quite inexplicable except for the evidently great concentration of energy here referred to, which, in consequence of this conspiring of inertia and reduced resistance, brings the total effort upon a comparatively limited portion of the material, producing the short fracture with its granular surfaces, which is the well-known characteristic of sudden rupture.

Any cause acting to produce increased density, as reduction of temperature, evidently must intensify this action of suddenly applied stress.

The liability of machinery and structures to injury by shock is thus greatly increased, and it is quite uncertain what is the proper factor of safety to adopt in cases in which the shocks are rapidly produced. This uncertainty must remain until further experiment shall be made the basis of a correct mathematical expression of the natural laws involved in the problem.

Meantime, the precautions to be taken by the engineer are: To prevent the occurrence of shock as far as possible, and to use in parts exposed to shock, light and elastic members, composed of the most ductile materials available, giving them such forms as shall distribute the distortion as uniformly and as widely as possible.

22. The behavior of materials subjected to sudden strain is thus seen to be so considerably modified by both internal and external conditions, which are themselves variable in character, that it may still prove quite difficult to obtain mathematical expressions for the laws governing them. It is not improbable, however, that an approximation, of sufficient accuracy for all cases which frequently arise in practice, may be obtained by a study and comparison of experimental results obtained, as above, by the method here adopted, and one which seems peculiarly adapted to the work.

A carefully-conducted series of experiments giving quantitative results would be of great value. Without such a research no reliable knowledge can be obtained of the law of depreciation, and no useful formulas can be devised for use in calculation. The experiments made by the writer are not yet sufficiently numerous or precise to serve as data from which to deduce equations.

23. The Elasticity of the Metals.—The examination of the "elasticity line" will be found to present some facts of interest.

It will be seen that, in every case, the line produced by the descent of the pencil is not precisely coincident with that formed by its rise. This is not due to the friction of the machine, as that would not cause the decided difference observable in the form of the curve. It may be partly due to the fact that the set produced is partly temporary.*

An attempt was made to determine its law by the following method:

A steam gauge having a recording apparatus, in which the paper was moved horizontally, at a uniform rate, by a well-constructed clock, was kindly furnished by the Messrs. Edson, of the New York Recording Gauge Co.

This was set up by the side of the machine, upon a stand on which could be

* Compare Kirkaldy, p. 83, where experiments, which are possibly affected by the action of *vis viva*, indicate a very similar effect.

* Morin, "Resistance des Materiaux," p. 10.

clamped the test piece. The latter carried a light, long pencil holder, so arranged as to traverse the paper in a direction at right angles to that of the motion given it by the clock. An angular motion in the specimen of 0.05 deg. would be readily observed. The specimen was given a degree of torsion of from 10 deg. to 360 deg., in different cases, and was then rapidly transferred to the stand where the restoration of form would record itself upon the moving paper, forming a curve of which the ordinates would represent the restoration of form, and the abscissas would be proportional to the time.

In all cases observed, the restoration of form, by loss of temporary set, was so rapid as to have become completed before the specimen could be placed in the recording apparatus, and the record made a straight line invariably.

The conclusion which has finally been deduced from a study of the diagrams obtained is, that the peculiar feature here alluded to is a consequence of an internal molecular friction, the existence of which has already been long suspected by the writer, and probably by many other experimenters.

An illustration of a similar action probably occurs in the behavior of iron under magnetic action. Magnetization produced in bars of various qualities of iron and steel during important researches of Dr. Joule* and Prof. Tyndal,† proved this behavior to be common to all, when the change of form was produced, within a very minute range even, by magnetic force. Dr. Mayer has more recently‡ examined this peculiar form of molecular action with great skill and thoroughness. Its existence is undoubtedly well proven, and the lines, above referred to, on the strain-diagrams seem to exhibit its effect very clearly. Possibly the rise from *f* to *g*, No. 118, Plate III., is due to such friction.

24. The evident proof found, in the parallelism of all elasticity lines in each diagram, of the fact, first noted by some of the earliest experimenters in this field, that elasticy remains quite unimpaired up to the point at which rupture commences, has been already adverted to.

Coulomb describes a series of curious and instructive experiments which may assist in determining the molecular action occurring in these instances where great distortion and great permanent displacement of particles takes place without loss of elasticity.*

He found this to occur, not only with metal wires, but with threads of fine clay, 1-12 of an in. in diameter and 11 ft. long, which could be twisted 5½ turns repeatedly without set and without apparent loss of elasticity. Turning the thread through a wider range of torsion, it always returned but 5½ revolutions, and in each new position of set exhibited the same elasticity as before.

The explanation of this action, as illustrated by the strain diagrams of Plates II. and III. and by Coulomb's experiments, is probably also to be found in the phenomenon of flow of solids. The restoration of cohesion, in bodies actually separated, exhibits the extent to which this action may proceed. Two freshly cut surfaces of lead when brought together, with a moderate pressure cohere firmly, and plates of glass, laid one upon another, sometimes "seize" each other so firmly that they are cut and worked as one piece.† The welding of iron is another and a very familiar illustration of the same action. Cohesion may therefore be actually destroyed and renewed, and molecules may move among each other, changing completely their relative positions, without loss of either strength or elasticity.

The result of these experiments on metal are important as exhibiting the error of the opinion hitherto entertained by many physicists and engineers, among whom was the writer,‡ that straining metal might weaken it, even when rupture did not commence, and even where no condition of internal strain was induced. It has been here shown that elasticity remains unimpaired, and resistance continually increases up to the point at which incipient fracture takes place. No well proven exception to this law has been observed.

25. While comparing the inclination of the elasticity lines with the initial line, to determine the pressure and the amount of internal strain, it has been noticed that more or less strain seems almost invariably to exist, but that the amount, as indicated

* "Philosophical Magazine;" 1874.
† "Researches on Diamagnetism," etc., 1870.
‡ "Effects of Magnetism in changing dimensions of iron and steel bars," by A. M. Mayer, Ph. D.; Stevens Institute of Technology; 1872. "American Journal of Science and Arts;" 1873.

* "Lecture Notes on Physics;" Mayer. "Journal Franklyn Institute," 1868.
† Miller: "Chemical Physics;" p. 67.
‡ "Journal Franklin Institute."

by the difference in inclination of the two lines, is not always as well shown by the greater or less curvature of the initial portion of the diagram. The probable reason would seem to be that this strain is not always uniformly distributed. Were the strain considerable and uniformly distributed, the initial line would be strongly convex toward the base line, and would have the parabolic form. Absence of strain is indicated by a straight line rising regularly to the elastic limit, or, in many cases where the elastic limit is very low, and when the material is inelastic and flows without tendency to recoil, concave toward the base, and parabolic. Irregularly distributed strain would modify the parabolic curve, and the amount of strain would determine the total curvature.

The initial and elasticity lines have, therefore, great interest as revealing important and otherwise unrecognizable properties of the material.

It has been remarked that the difference of inclination just referred to, proves the truth of the assertion of Hodgkinson that every load produces a set. It can now be readily seen why this should usually be the fact, and also that, although it is true, it does not necessarily indicate injury of the material.

Since, in its ordinary state, many sets of particles are usually in a condition of maximum strain, the slightest application of external force to the piece will destroy the existing equilibrium among these conflicting forces within the mass, producing a change of form, and either rupturing or producing a flow of those particles which are most strained, and thus causing a new condition of equilibrium, the piece returning only approximately to the original form when relieved. The greater or less the applied force, the greater or less the number of displaced particles, but it is only when the set becomes nearly proportional to the distortion that it assumes the character in which it is looked upon as a serious effect.

With perfectly homogeneous materials, free from internal strain, no such action would be noticed, and the earliest set would occur beyond the elastic limit, which limit is here considered to be attained when the set becomes proportional to the distortion.

26. The very minute range of distortion within the elastic limit is shown by the strain-diagrams very beautifully. This point is usually reached with the first 5 deg. of torsion, and where internal strain has been eliminated it is frequently found within 2 deg., the corresponding extension being much less than .0001.

Captain Rodman, who has made the most delicate determination yet published,* detects a set of 0.0000014 after an extension of 0.00027 in a specimen of cast-iron, and the elastic limit, as here defined, is reached after an elongation of about 0.0003, the point not being, however, very accurately determinable on account of the insensible change of rate, as already observed in the strain-diagrams of cast-iron.

The immense magnification, on the strain-diagrams, obtained with the torsion machine, of the elongation at the commencement of the curve enables the behavior of the materials within this minute, yet most important, portion of the entire range, to be perfectly represented, and permits its examination in a most satisfactory manner.

27. *The Influence of Variations of Temperature.*—The effect upon the mechanical properties of metal of variations of temperature has long been a subject of debate, and one which has not even yet been satisfactorily settled by experiment.

A priori it would appear that, in a perfectly homogeneous material, entirely free from internal strain, change of temperature would produce an alteration of strength and of ductility which would both be the reverse, in direction, of the variation of temperature.

The forces acting to produce mechanical changes being, probably, cohesive force, on the one hand, resisting external forces tending to produce distortion or rupture, while the force produced by the energy of heat motion conspires with external force to produce that distortion, and the molecules being, at every instant, in equilibrium between the force of cohesion, on the one side, and the sum of the other two forces mentioned, on the other, variations of form must ensue with every change in the relative magnitude of these forces. A change of temperature produced by an increment of heat energy, it would appear, must produce a reduction of cohesion by separation of particles, and the opposite change must cause an increase of cohesion by their ap-

* "Experiments on Metals for Cannon," etc., Rodman, pp. 157-167.

proximation. Increase of temperature, by reducing the range of action of cohesion by separating particles, and causing them to approach the limit of reach of cohesive force, would reduce ductility, and the opposite change of temperature would increase extensibility. The effect on resilience, the product of ductility and strength, would evidently be still more marked than the variation of its factors.

The peculiar behavior of zinc, and the often observed brittleness of iron, at low temperatures, have given cause for doubting the truth of the above statement, and until the phenomena accompanying variations in homogeneousness of structure and composition, and the introduction or removal of internal strain, have been very thoroughly investigated, it cannot be anticipated that the subject will become well understood. The character of polarity—that force of which the presence constitutes the distinguishing difference between solids and liquids—remains to be determined, and its determination may be expected to throw important light upon this subject.

Experiments of both physicists and engineers have failed, up to the present time, to give as much and as precise information as is needed to determine satisfactorily what rules should govern the proportions of structures, whether carrying dead loads or subjected to shocks or blows, at any given temperature below the usual range, or even at the low temperatures to be met during every winter in the latitude of New York.

In a paper recently published* on "Molecular Changes produced by Variations of Temperature," the writer gave the results of a careful investigation of the experimental work previously done, by both philosophers and engineers, in researches bearing upon this important question.

28. The conclusions, as there reached, were the following:

1. That the number and the nature of those molecular forces which determine the physical condition of matter are not yet fully ascertained, but that these forces manifest themselves in, at least, three distinct modes of action, and, as thus exhibited, they are known as repulsion, cohesion, and polarity.

2. That the force of repulsion is, apparently, heat motion, or some closely-related phase of energy. That the force of cohesion bears some resemblance to that of gravitation, but seems not to be identical with the latter; and that the force of molecular polarity, which determines the molecular relations of position, seems to bear some distant relation to that of magnetic polarity.

3. That the law which governs the variations in intensity of these forces with changes of intermolecular distances, is undetermined, and that it has not been expressed by any mathematical formula, except approximately, and for a limited range.

4. That the magnitudes of the intermolecular spaces, and consequently the volume of any mass, are variable with changes in the relative magnitudes of the forces of cohesion and repulsion.

5. That the resistance offered to change of form is determined by the relations in intensity of the forces of polarity and those forces which determine intermolecular distances.

6. That, at the "absolute zero" (—461.2 deg. Fahr.), cohesion, and consequently the strength, of the material has, probably, its maximum value, heat-energy having disappeared.

7. That, at very high temperatures, heat-energy exerts a separating force upon particles, which entirely overcomes the other forces, and matter, assuming the gaseous state, requires the action of extraneous forces to preserve its volume unchanged.

8. That, at intermediate points, matter, in either the solid or the liquid state, exhibits a definite degree of separation of molecules which is determined by the intensity of the repulsion due to heat motion, a position of equilibrium being assumed, which, with the same substance, is invariable for the same temperature. The application of some kind of force is required to disturb this equilibrium and to produce change of volume. The amount of this force is determined, for any given extent of disturbance, by the maximum value of cohesion for the substance and the quantity of heat which has been required to raise it from the absolute zero of temperature.

The sum of the applied force and the force consequent upon the presence of heat motion must exceed cohesive force to produce dilatation, while this cohesive force, added to externally-applied force, must ex-

* "Iron Age," June, 1873; "Van Nostrand's Mag.," July, 1873; "Jour. Frank. Inst.," 1873; "London Jour.," Jan., 1874. Also in pamphlet, p. 29. D. Van Nostrand.

ceed the force of repulsion to produce diminution of volume.

9. That the distinction between the solid and liquid states of matter seems due to the action, in the former, of the force of polarity, which gives stability of form, while, in the latter, this force is extremely feeble, disappearing altogether when the boundary line between the liquid and gaseous states is reached.

That combined stability and elasticity of volume may be produced by the equilibrium of attractive and repulsive forces, but that stability and elasticity of form demand the co-existence of cohesion and polarity.

10. That the general effect of increase or decrease of temperature is, with solid bodies, to decrease or increase their power of resistance to rupture, or to change of form, and their capability of sustaining "dead" loads.

11. That the general effect of change of temperature is to produce change of ductility, and, consequently, change of resilience, or power of resisting shocks and of carrying "live" loads. This change is usually opposite in direction and greater in degree than the variation simultaneously occurring in tenacity.

12. That marked exceptions to this general law have been noted, but that it seems invariably the fact that, wherever an exception is observed in the influence upon tenacity, an exception may also be detected in the effect upon resilience. Causes which produce increase of strength seem also to produce a simultaneous decrease of ductility, and *vice versa*.

13. That experiments upon copper, so far as they have been carried, indicate that (as to tenacity) the general law holds good with that metal.

14. That iron exhibits marked deviations from the law between ordinary temperatures and a point somewhere between 500 deg. and 600 deg. Fahr., the strength increasing between these limits to the extent of about 15 per cent. with good iron. The variation becomes more marked and the results more irregular as the metal is more impure.

15. That above 600 deg. F. and below 70 deg., the general law holds good for iron, its tenacity increasing with diminishing temperature below the latter point, at the rate of from 0.02 to 0.03 per cent. for each degree Fahrenheit, while its resilience decreases in a higher but not well determined ratio for good iron, and to the extent of reduction to one-third its ordinary value, or less, at 10 deg. F. when cold short, and, in the latter case, the set may be less than one-fourth that noted at a temperature of 84 deg. Fahr.

16. That the viscosity, ductility and resilience of metals are determined by identical conditions, and that the fracture of iron at low temperatures has, accordingly, been found to be characteristic of a brittle material, while, at higher temperatures, it exhibits the appearance peculiar to ductile and somewhat viscous substances. The metal breaks in the first case, with slight permanent set and a short granular fracture, and in the latter with frequently a considerable set and a form of fracture indicating great ductility. The variation in the behavior of iron, as it approaches a welding heat, illustrates the latter condition in the most complete manner.

17. That the precise action of the elements with which iron is liable to be contaminated, and the extent to which they modify its behavior under varying temperature, remain to be fully investigated, but that the presence of phosphorus, and of other substances producing "cold shortness," exaggerates, to a great degree, the effects of low temperature in producing loss of toughness and resilience.

18. That the modifications of the general law with other metals than iron and copper, and in the case of alloys, have not been studied and are entirely unknown.

19. That these conclusions are sustained by experiments of both physicists and engineers.

"The practical result of the whole investigation is that iron and copper, and probably other metals, do not lose their power of sustaining "dead" loads at low temperatures; but that they do lose to a very serious extent their power of sustaining shocks or of resisting sharp blows, and that the factors of safety in structures need not to be increased in the former case, where exposure to severe cold is apprehended, but that machinery, rails and other constructions which are to resist shocks, should have larger factors of safety, and should be most carefully protected, if possible, from extreme temperatures."

29. The conclusions above given were deduced from the physical investigations of Boscovitch, Coulomb, Henry, Powell, Cagniard de la Tour, Andrews, Faraday, Wartman, Robison, Gaudin, Thompson, Rankine

and others, and from the more purely technical researches of Professors Johnson and Norton, Fairbairn, Kirkaldy, Brockbank, Joule, Spence, Styffe and Sandberg.

An apparent discrepancy of results from which some experiments seemed to indicate weakness, and others strength of metals as a consequence of reduced temperature, was explained by the fact that those which seemed to prove the first conclusion, were cases in which the metal was tested by blows, and those proving the reverse were tests made by steady strain. The deduction 11, made above, that the result of change of temperature, by producing changes of ductility, which were the reverse of those produced in tenacity, and that the same bar might thus exhibit a higher resistance to static stress while less capable of resisting shock, explained the seeming contradiction.

30. It was evident that, to determine satisfactorily the real effect of changes of temperature, it was necessary to obtain a series of experimental determinations of the simultaneous action of such variations upon both strength and resilience. Such experiments could readily be made by the method here pursued, and a considerable number of observations are represented by strain-diagrams on Plate III.

In these experiments, the machine and the test pieces were placed in the open air, where, changing in temperature with the atmospheric changes, no error could arise by transfer of heat during the experiments. The machine and the specimens submitted to test were always of the same temperature.

The mildness of the past winter has precluded the determination of the behavior of iron at temperatures very far below the freezing point, the lowest reached being 10 deg. Fahr.

This is the more to be regretted, since, as will be seen, there exists a possible change of law near the Fahrenheit zero, and it is extremely important to ascertain whether this indication of an anomaly arises from irregularity in the quality of specimens, nominally of the same grade, or whether it is a real variation of the effect of change of temperature.

As no previously made experiments combine, in the manner here presented, the various effects of heat upon the mechanical properties of the metals, the results obtained are given as a beginning, and the conclusions which are deduced from them are given as merely probable, while it is to be hoped that other members of the profession, who may be so situated that they can readily continue the work at points in the north and northwest where a temperature far below zero is reached, will make more complete and instructive researches during succeeding winters.

It is apparently quite impossible to avoid error if the attempt is made to experiment with specimens cooled down by freezing mixtures, and the writer would only feel justified in presenting the results of out of-door work.

31. Referring to Plate III., the strain-diagrams of the best, and of medium tool steel, of German and double shear, of the several grades of iron and of copper and bronze are given, for temperatures from 70 deg. down to 10 deg. Fahr. A diagram is also given in which the horizontal scale of the plate is taken to represent absolute temperatures on a one-fourth scale, and at ordinates representing respectively 10 deg., 18 deg., 25 deg. and 70 deg., the resistances of the several specimens are laid off, and dotted lines connecting them indicate the rate of variation of strength with temperature.

It will be seen that with the single exception of a scrap gray cast iron, presumably unusually impure (Nos. 25, 26), the effect seems invariably to have been a simultaneous increase of both strength and ductility with decrease of temperature to 18 deg. and usually to 10 deg. from 70 deg. Fahr. In the case of the cast-iron, the increase of tenacity and reduction of ductility at the lower temperature are equally well exhibited, and the result is a slight decrease of resilience.

It will be noticed that the general trend of the lines in the diagram prepared for comparison of results, is very evidently towards a point on the scale (250 deg.), corresponding to a temperature of 1,000 deg. above the absolute zero, at which point, were the diminutions proportioned to temperature, the metals would lose all cohesion. Since, however, the law, as determined approximately by the Committee of the Franklin Institute, is expressed by a parabolic equation, the fact that their melting points are nearer 3,000 deg. or perhaps 4,000 deg. Fahr. above the absolute zero, does not conflict with the results of experiments.

32. Comparing the several specimens of "good cast-steel," it is found that the four (Nos. 46, 47, 49, 50) whose strain-diagrams are given, evidently differ nearly as much in their individual properties as in their alteration by temperature. The two pieces tested at 70 deg. Fahr. give a mean of strength, ductility and resilience, which is less than either of the other specimens. The strongest piece was broken at 18 deg., while that tested at 10 deg. is very nearly its equal in that respect, and is more than 10 per cent. better in extensibility and nearly 10 per cent. superior in resilience. The difference between the specimens tried at 10 deg. and at 70 deg. (average of the two) is about 15 per cent. in ductility and resilience, and rather more than 5 per cent. in tenacity. The piece tested at 10 deg. has a limit of elasticity exceeding that of the specimens tested at 70 deg. in about the same proportion.

The double shear steels are irregular, as would be expected from their method of production, but the greatest ductility is shown by the specimen tested at 25 deg. F., and the greatest tenacity by that broken at 25 deg. also. The weakest is that tested at 70 deg., its loss of strength, ductility and resilience, being very striking. The position of the elastic limit varied with that of the ultimate strength. "German" (English) steel exhibits greatest strength at 18 deg. (No. 60), greatest ductility at 70 deg. (No. 58), and greatest resilience at 25 deg. (No. 25).

"Medium crucible" steels seem strongest at 18 deg. Fahr., most ductile and equally resilient at 25 deg., and weakest, least ductile and least resilient at 70 deg.; Nos. 78, 54, 70 are their strain-diagrams.

Swedish irons (Nos. 99 and 100) were tried at 25 deg. and 70 deg., and the result is again that the greatest resistance and greatest extensibility occur at the lowest temperature, the difference here amounting to something less than 10 per cent. at the elastic limit and about one-half as much at the maximum.

A piece of common iron was selected by the blacksmith from his stock as "the worst specimen of cold short iron in the shop." The two specimens, Nos. 130 and 132, were taken from the bar and tested at 10 deg. and 70 deg. Fahr., respectively, with a result which is unexpectedly similar to those already given in the variation of ultimate strength, ductility, and resilience. The increase of strength at the lower temperature is apparently nearly 15 per cent., the increase of ductility about the same, and the increase of resilience 30 per cent. At the elastic limit this is reversed, however, the specimen tested at 70 deg. showing the highest elastic resistance. That broken at 10 deg. exhibits a very considerable amount of internal strain, to the presence of which may be attributed the exceptional behavior of these pieces. A similar difference, but opposite in direction and less in amount, is noticeable in the Swedish irons, Nos. 99 and 100.

Copper, Nos. 133 and 134, and bronze, Nos. 137, 138, both show a considerably greater strength at 10 deg. than at 70 deg., and a slightly improved ductility. The increase of tenacity and resilience amounts to 20 per cent. and 30 per cent. respectively, the ratio being slightly greater at the limit of elasticity.

Cast iron exhibits the most striking increase of tenacity, the ratio of increase being above 30 per cent, and in ductility having a mean value of 50 per cent. One specimen, No. 25 *C*, has a serious defect of internal strain, but, eliminating that by cutting off the sharply-curved lower portion of the line, it would coincide very exactly with the companion specimen, No. 25 *D*, broken at the same temperature, 25 deg.

33. It would seem, after a study of these experiments and after a comparison with those described by other experimenters, that, although a considerable irregularity, due to differences in material nominally of identical character, tends to obscure them, we may feel some confidence in drawing the following conclusions in modification and extension of those already given in article 28.

(20.) That, with pure, well-worked metals, the principle enunciated in article 28 is fully illustrated, and a decrease of temperature is accompanied by increase of strength, ductility and resilience.

(21.) That materials which are impure and irregular in character may exhibit exceptions to, and even reversals of, that principle in changes of ductility, and, while increasing in power of resisting simple stress, may lose their power of resisting shock, by a diminution of temperature.

We may hence feel confidence that, with really good iron or steel, we are not exposed to seriously increased danger of failure of structures at such low temperatures as frequently occur in this latitude.

There is no reason to believe that the familiar effect of phosphorus in "cold shortening" iron and steel, when cold, has its maximum effect at ordinary temperatures. The experiments of Sandberg would seem to prove this effect to be intensified continually with decrease of temperature.

34. Since the above research was concluded, the writer has become indebted to the thoughtful kindness of Mr. Chas. Francis Adams, Jr., for reports, one of which is that of the Mass. R. R. Commissioners for 1874, containing (page 144, *et seq.*) the result of an investigation of the cause of rail breakage on a considerable number of railroads in the United States and Canada. The conclusions given are that "cold does not make iron or steel brittle, or unreliable, for mechanical purposes," and that "it was not the rule that the most breakages occur on the coldest days." The introduction of steel in place of iron rails, has caused an almost complete cessation of the breakage of rails (p. 150).

The deduction which would seem proper in comparing these latter statements with the work of Sandberg would seem to be, simply, that the latter experimented with cold short rails. The same conclusion is given in Sandberg's own statement of the difference between Welsh and French metal.*

35. We still require, to give us reliable information regarding exceptional cases, a series of experiments to determine the action of excessively low temperature, and whether the apparent change of law near the Fahrenheit zero is a natural or an artificial phenomenon. We need to learn precisely the effects of sulphur, phosphorus, and silicon at extremely low temperatures. We need, also, and especially, to learn by experiment, whether extremely low temperatures occurring during our winters, produce a serious effect upon iron and steel by the introduction of internal strain as the material decreases in volume and increases in density.

The uncertainty still existing as to the extent to which increased density at low temperatures and reduction of tenacity under sudden strains at all temperatures—phenomena which have been revealed but not measured during the investigations here described—will be recognized by every member of our profession as one which it is exceedingly important to remove. It is hoped that it may not long remain, for it is evident that, although perhaps improbable, it is not impossible that, notwithstanding the increase of both tenacity and ductility by reduction of temperature, these causes may still conspire to produce increased tendency to yield before shock at some unknown low temperature.

36. The peculiarities of fracture, which have been alluded to, are exhibited in the accompanying Plate.

Figures 15 and 16 exhibit the behavior of a bar of iron made at Catasauqua, Pennsylvania, as broken by Mr. Oliver Williams, at 70 deg., and, again, at 20 deg. Fahr. It is selected from among the specimens in the cabinets of the Stevens Institute of Technology. The fracture at 70 deg. (Figure 15) has the fibrous fracture and all the characteristics of what is generally considered a tough and ductile iron. That at 20 deg. (Figure 16) resembles the break produced by a quick blow in good iron, or by any treatment at ordinary temperatures of a cold short iron. Were the conditions stated not known it would be supposed that irons like Nos. 1 and 16, Figures 5 and 6, were combined in a single bar.

Figures 17 and 18 illustrate strikingly the difference between the specimens of copper, Nos. 87 and 133, which have been already described, and of which the strain-diagram of the one is shown in Plate II., and of the other in Plate III. No. 87 was cast in green sand, and broken at 70 deg. Fahr., while the other was made from the same ingot, but cast in dry sand and broken at 10 deg. Fahr.

The first is unsound in structure in consequence of the dampness of the mould, and exhibits a peculiar radiated texture which is probably due to the same cause. The second is distinguished by its compact, homogeneous structure, probably due to the freedom of the mould from vapor and gases. It presents a beautiful crystalline fracture, which is probably due partially, if not principally, to the low temperature at which it was broken.

These fractures are extremely interesting from the strongly typical features which they exhibit as characteristic of the peculiar conditions under which they were produced.

RESUME.

37. *En résumé*, a review of this investigation of the nature of, and the influences

* P. 157; conclusion 3; p. 158, line 4; p. 132, Nos. 21, 24.

affecting, the distortion and rupture of metals, it would seem allowable to accept, as extremely probable, the following

GENERAL CONCLUSIONS.

1. That accurate strain-diagrams, in which the behavior of the material, as distortion progresses, and especially about the elastic limit, afford a means of acquiring valuable information respecting the strength, elasticity, homogeneousness, ductility and resilience of materials, and of tracing the modifications induced by variations of treatment and of composition.

2. That internal strain plays a most important part in determining the behavior of materials strained by either static or dynamic stress.

3. That the time during which applied stress acts, is an important element in determining its effect, not only as an element which modifies the effect of the *vis viva* of the attacking force and the action of inertia of the piece attacked, but, also, as modifying seriously the conditions of production and relief of internal strain by even simple stresses.

4. That with good materials, cold does not produce injury, but actually improves their power of resisting stress and increases their resilience.

5. That the influence of impurities, of various methods of manufacture, of changes of density with temperature, and of the causes which produce a concentration of the action of rapidly produced distortion and of quick blows, are subjects which still require careful investigation.

6. That experiment confirms the theory as to the behavior of materials, homogeneous in composition, structure, and strain, as expressed *à priori* in 27, and hence a probable deduction that the force of molecular repulsion is heat motion.

ON SIMPLICITY AS THE ESSENTIAL ELEMENT OF SAFETY AND EFFICIENCY IN THE WORKING OF RAILWAYS.

By Captain HENRY WHATLEY TYLER.

(*Continued from page* 87.)

The next branch of the subject is that which refers to the preservation of intervals between the trains. It is obvious that as long as any interval, whether of time or space, is actually preserved between any two trains, they cannot come into collision with one another. Collisions are liable to occur between trains following each other on the same line of rails; or, within fixed signals, at stations, sidings, junctions, etc. The greatest number of collisions occur at stations or sidings, and within fixed signals. In 1872 there were 91 cases of collisions at stations or sidings, 32 cases at junctions, 22 cases from trains following one another, 5 from trains meeting in opposite directions, and 34 from passenger trains being wrongly turned into sidings or otherwise through facing-points—out of a total of 238 train accidents investigated by the Board of Trade.

As soon as trains were run with sufficient frequency to endanger one another, it became obviously necessary to establish some system of preserving intervals between them; and the practice obtained of allowing a certain number of minutes to elapse, not only between their times of starting, but also between the times at which they should pass intermediate stations, and any junctions, or level-crossings in charge of gate-keepers, or other points at which servants of the companies were stationed; and the plate-layers were also on many lines expected to warn any train which appeared to be following too closely upon a preceding train. In tunnels it was further found necessary to prevent one train from entering at one end until the preceding train had passed out at the other end, and this was the commencement of what is called the block system, by means of which an interval of space was secured, in place of an interval of time, between the trains. The time interval which came to be generally adopted was 5 minutes of danger and 5 minutes of caution; that is to say, the trains were to be kept 5 minutes apart from one another in their running, and were to be cautioned if they were not 10 minutes apart. But in the case of goods or slow trains preceding fast non-stopping trains, still greater intervals were required; and sometimes periods of 15 or 20, or more, minutes, became, as the differences in speed increased, insufficient

safely to admit of heavy goods trains being started in front of express passenger trains. It was recognized at an early period that the simplest and best mode of avoiding collisions at stations and sidings was by keeping the main lines clear for passenger trains; and accordingly it was provided in the regulations that the main lines should not be interfered with, in the way of obstructions or shunting, within 10 min. of a passenger train being due, and, sometimes, within 15 min. of an express train being due. The proposal to divide the line into telegraphic sections, and thus to preserve space intervals between trains, was made by Mr. (now Sir William) Cooke, as far back as 1842, and was first practised, it is believed, on a portion of what is now the Great Eastern Railway, in 1844; and, subsequently, a train telegraph system was established on portions of the London and North-Western Railway. This latter, however, was not a block system, or a space system, but a time system worked with the aid of telegraph instruments; and it is now known as the permissive system. Under this system, the line between London and Rugby was divided into sections averaging rather more than two miles in length, and the signalmen were required to telegraph the trains to one another—to turn their signals to danger on the passage of every train—keep them at danger for 3 min., or more in certain special cases—to exhibit caution signals after the expiration of the 3 min.—and only to give clear signals again after receiving "line clear" from the next cabin in advance. In the case of tunnels, no second train was allowed to enter until the preceding train had been signalled as "out," and a space system was thus introduced; but on other sections two or more trains were allowed to be travelling at the same time; and even if a second train reached a cabin before a preceding train had passed the next cabin, and within the three minutes prescribed for the exhibition of the danger signal, the engine driver was, after his train had been brought to a stand, to be warned of a train in advance and to be allowed to proceed. This system is worked by needle instruments, the needles being pegged over to "line blocked" or "line clear," as the case may be; and the vertical position of the needle is taken to indicate, either that the telegraph is out of order, or that the line is obstructed. On certain telegraph posts special loops of the telegraph wires are provided, to be broken by the guards or brakesmen of trains in the event of sudden obstructions; and in long tunnels the loops are inclosed in boxes at intervals of about 100 yards. By breaking these loops, the guards or brakesmen are enabled to inform the signalmen at either end of a section, of an up-line, or a down-line, or a third line, or two or three lines, being suddenly obstructed by an accident to a train.

As regards the block system, there are many descriptions of means of instruments for working it, and various rules and regulations applicable to it on different lines of railway. The main principle involved is, simply, by the division of a line into block sections, and by allowing no engine or train to enter a block section until the previous engine has quitted it, to preserve an absolute interval of space between engines and trains. This may be done mechanically or electrically. Any means of communication with which the signalmen may be provided will enable them to inform one another of the approach of a train, of its entrance into a block section at one end, and of its exit from that block section at the other end. The raising or lowering of signal arms inside or outside the cabins, the beats on mechanical gongs or bells, the beats on electric gongs or bells, or the working of different descriptions of telegraph needles or instruments, may any of them be employed to afford indications of this description. But in many cases it is considered necessary to give further information, such as the description of the train, whether a through or stopping passenger train, or a goods or mineral train, or a ballast train, or a light engine; and to provide, besides the signals for line clear or line blocked, separate indications also for an acknowledgment signal, for an attention signal, for an obstruction signal, for an error signal, for a testing signal, for notice of shunting going on at a station, for a train to be shunted out of the way to allow another to pass it, or for a train to be stopped and examined in the event of something suspicious or wrong having been observed in it. Then, again, on some lines distinction is made between passenger trains, express goods or cattle trains, through goods or mineral trains, stopping goods, mineral, or ballast trains, and as to whether these are approaching, or whether they have entered the section. These and other indications are differently

made on different lines. In some cases the block instruments are used for them; in some cases they are made exclusively on electric bells; in some cases single-needle speaking instruments are employed. On certain lines, the block system is used for the protection of junctions; no two trains which could come into collision with one another being allowed to approach a junction at the same time. On other lines it is not so used, or is only used in the case of junctions approached on heavy falling gradients, or, under other circumstances of extra risk. On some lines record books or registers of the trains are carefully kept, and are found to be valuable safeguards against irregularities, the working of each signalman being checked by the record book of the signalman on each side of him. On other lines record books are not employed. Certain railways are worked on the block system by bells only; others by bells and block instruments, so as to afford the aid and evidence of sight as well as sound to the signalmen; and others by bells, block instruments, and speaking instruments. When the bell code includes a great number of indications, then the number of beats required, amounting to 10, or even 14 and 15, become so numerous that the men are liable to mistakes in counting them; and especially with the system sometimes employed of making, for instance, six beats mean one thing and three beats twice repeated, some other thing. It is, in any case, all important that the two indications "line clear" and "line blocked" (from whatever cause) should be entirely distinct from all other signals; and the necessity for this was demonstrated in a recent accident, one cause of which was that an acknowledgment signal was mistaken for a line clear signal. One important question in the working of block systems is, the particular time when line clear should be given after an engine or train has passed a section cabin or signal. The lengths of the sections vary, necessarily, according to the nature of the traffic and with local circumstances. They may be measured by miles in some cases, and by yards in other cases. Whatever their lengths, if one train has passed out of a section before another train is admitted to it, there must at the period of admission of the second train be an interval of space equal to the length of the section between the two trains. But, supposing the first train, on passing out of the section, to be brought to a stand immediately after passing the section signal, then the second train, being admitted to the section, may also run up to that section signal and to the tail of the preceding train, and the interval between the trains will be reduced to nil. An engine-driver, overrunning a signal to only a slight extent, may, in such a case, come into collision with a preceding train. Different companies meet this question in different ways. On some railways the line is considered clear when the last vehicle of a train has passed the section signal; on other lines this is the case except during fogs and snowstorms; on others, again, different specified stations are differently provided for; and on other lines a difference is made in this respect between goods and passenger trains. The Northeastern rule, for instance, runs as follows: "In regard to passenger trains, the line in the rear section must always be considered blocked until the preceding train has either been shunted clear off the main line or has passed the advance semaphore where such signal is provided, or, where there is no advance semaphore, has passed the section home signal at least 300 yards on its journey in the next section." The question of protection by the distant signals in the case of trains so brought to a stand beyond the home or section signals, or in the case of an obstruction in a block section, formed the subject of a memorial in August, 1873, by the engine-drivers in the employment of this company, and the officers of the company appear to have acceded to the reasonable demand in this respect, of their engine-drivers.

The following is a copy, as received at the Board of Trade, of this memorial addressed to Mr. Fletcher, Locomotive Superintendent of the North-Eastern Railway, and stated to have been signed by 650 engine-men on that railway:—

"We, the undersigned, engine-men under your employ, beg most respectfully to ask you to intercede on our behalf for the better working of the block signals, as the way it is worked is contrary to the working on all other railways, and should the same practice be continued, the most disastrous consequences may ensue as bad weather approaches.

"What we complain of is the not working of the auxiliary or distant signal when a train is required to stop, as it is impossible to stop at the home signal if the distant signals are not worked, as we cannot see

the home signals at many stations and block cabins till we approach within a short distance of them; and likewise we beg to call your attention to the slackness of the auxiliary wires at stations and block cabins as well, as they are kept so slack they will not raise the signals as we can understand them.

"Sir,—Should you not be able to get any of these bad arrangements altered, will you, please, cause more time to run the trains, so that we can stop at all cabins to ascertain if the road is clear for our safety as well as the public at large.

"We remain,

"Your most humble and obedient servants,

"ENGINE-MEN IN YOUR EMPLOY."

It is interesting to observe in this case that the engine-drivers, who are likely, as we are sometimes told, to become reckless in working under the block system, themselves took steps to induce their superiors to alter regulations which were not, in their opinion, and as the result of their experience, sufficient to enable them to work with confidence and safety. They appear virtually to have declined to work, and to be trained to work, under a system of risk to which, in their opinion, the regulations of the company—which differed from those of other companies—exposed them. But it is to be hoped that those who were concerned, and took part in this question, will relate accurately and fully what occurred; and what were the views of the engine-drivers on the one hand, and of the superior officers of the company on the other hand, on this subject. A strong desire also was expressed to the author in the course of a recent inquiry, on the part of the engine-drivers of the London and North-Western Railway, running with fast through trains, to receive a caution signal, say at block-station A, when the line is not clear between block-stations B and C; or, in other words, to receive an additional section of warning by a caution signal in the event of an obstruction; as well as to have a greater proportion of break-power under their command. A tail-board by day as well as a tail-lamp by night is of great value in enabling each signalman to see at a glance as a train passes him whether the whole of it has gone by, and is now very commonly employed.

In the working of single lines by telegraph, a risk is incurred which does not arise in the case of double lines. In the event of irregularities in the running of the trains, it becomes necessary to alter the crossing places of trains proceeding in opposite directions; and from time to time accidents have occurred in this country and elsewhere in consequence of misunderstandings in making such alterations. Such accidents led many years since to the establishment of, and to the preference by many for, the train-staff system of working single lines. In some cases a combination of train-staff and block-telegraph has been adopted, and this combination appears to afford, when it can be carried out, the greatest degree of safety. But the feeling in favor of working single lines by telegraph only appears again to have strengthened; and it must be admitted that it allows of greater freedom in dealing with the traffic, especially on lines of considerable length. It is most extensively practised in America, in India, and on the Continent of Europe.

Of all the difficulties that present themselves in railway working, the greatest is that of running trains in a fog. When the fog is so thick as to prevent the engine-drivers from seeing the signals, it then becomes necessary to inform them by other means of their condition; and, accordingly, plate-layers or porters are employed as fog-men, to stand near the signals, to place detonating signals on the rails, and thus to inform the engine-drivers of the indications of the signals; or they convey in some cases verbal directions from the signalmen. The greatest difficulty and danger are incurred either when a fog comes suddenly on, and the fog-men are not at their posts, or when it lasts for a long time, and the fog-men are required for duty for an excessive number of hours. The system is at best an unsatisfactory one. Much ingenuity has been displayed, and numerous proposals have been made, with a view to supplying audible signals, detonating or otherwise, to be worked mechanically with the ordinary signals, and thus to afford additional indications to the engine-drivers. But there is always danger in trusting to expedients which are exceptionally employed; and it can hardly be contemplated, in any case, to make every signal on a railway audible as well as visible, either ordinarily or exceptionally, to the engine-driver. Such complications of sounds as would result at busy places might indeed raise an outcry. The running of fast trains at high speed through a thick fog,

must, under any circumstances, with or without the block system, be attended with great risk; and the only practical arrangement appears to be to cause the speed of the trains to be reduced, during fog, according to its density, and according to circumstances; and to improve the organization of fog-men and their duties. Some of the companies do not allow the use of great-coats to men employed in winter on such duties.

There are, then, many points worthy of discussion as to the best mode of carrying out the details in the working of the block system. It has been found essential on very crowded lines, in tunnels, and other places of extra risk. The outcry against it of those chairmen of railway companies who at the same time take credit for its adoption, and who are indebted to it for the comparative safety of the traffic on the most crowded portions of their lines, cannot be considered to be very serious. The system of presumed time intervals has failed, because those intervals could not in practice be preserved; and the permissive system for reducing the time intervals by the aid of the telegraph, and sending trains timed to travel, and capable of travelling, at various speeds, one after another, into the sections, with a caution to each, may also be considered to have failed, because it does not afford sufficient protection to the traffic.

Under these time systems, collisions have occurred from engine-drivers slackening their speed to avoid collision with trains in front of them, and being run into by trains behind them. The greater the variety of speed between the trains, the more does the weakness of such systems become apparent. They may at first sight appear simple, but they involve constant confusion and uncertainty, because it is impossible to calculate in railway working upon the time intervals which it is safe to allow between trains under ever-varying circumstances; and no rules can possibly be laid down to meet all cases. Simplicity in working is, after all, best obtained by a system which will secure intervals of space between the trains; but a sufficient margin of space should be preserved between them at the end of a block-section as well as at the beginning of it; and to avoid confusion in working, not only should the signalmen have control over the traffic, but also the engine-drivers should have ample command of their trains; and there should further be lines and sidings sufficient to enable the work to be performed without disobedience to the regulations, and under good discipline. One great advantage, in fact, of the introduction of the block system lies in the necessary and simultaneous introduction of extra accommodation and appliances, without which it cannot be properly worked.

The safety of railway traffic from the great majority of serious accidents—namely, from various descriptions of collision and from accidents in connection with facing-points—thus depends mainly upon two classes of men, and upon the apparatus, the means, and appliances with which they are supplied. These two classes of men are the signalmen and the engine-drivers. The engine-drivers rely upon the signalmen to give them the proper indications, by means of their signals, as to whether the lines are clear or obstructed—as to whether the points are right or wrong; and the signalmen rely upon the engine-drivers to look out for and obey the signals that are made to them. The safe working of the traffic in this respect depends, therefore, upon a thorough understanding between these two classes of men. It depends, in fact, on the avoidance of mistakes, misapprehensions, or neglect (1) in the observance of signals by engine-drivers, (2) in the working of points and signals by signalmen, and (3) in the communications of signalmen with one another. In order to obtain the greatest degree of safety, it is necessary, as far as possible, to reduce the risk of such misunderstandings and neglect; or, in other words, pains must be taken to avoid confusion in working, and to substitute for it simplicity in working. Confusion in working must be more or less the consequence when rules and regulations are in force which cannot be carried out in practice—when hand-signals intended for one engine-driver may be received and acted upon by another engine-driver—when there is not a fixed signal for each purpose for which a signal is required—when signalmen or pointsmen are obliged to run about station-yards, at serious personal risk, to work points and signals, without being certain as to what train may next approach them, or when it may be expected—when, having a number of levers without locking apparatus in or around the cabin, they are liable to pull the wrong signals and point levers over for an approaching train—when, in the absence of necessary means

of communication, neighboring signalmen are liable to work at cross purposes with each other—when, in the absence of sufficient goods lines and sidings, station-masters and signalmen are compelled to allow the shunting, sorting, and marshalling operations of goods trains to be performed on the passenger lines, or goods trains to be moved from one main line to another, while passenger trains are due or overdue in one or both directions—when engine-drivers of through trains or stopping trains, at junctions or sidings, have not reliable signals, properly placed, to inform them distinctly, in each case, when they must stop or when they may go forward——when, under the permissive, or any other time system, they are told of trains being two, three, or any other number of minutes of time in front of them, without knowing how fast such trains may be able to travel, or what trains may similarly be allowed to follow them, and therefore what speed they should themselves maintain to avoid, on the one hand, a collision with a train in front, or, on the other hand, a collision with a train behind them—when, in long, heavy trains, timed to travel at high speed, they have not sufficient brake-power to enable them to bring the train to a stand within a reasonable distance—when they cannot depend upon the guard hearing their brake-whistles, and have only a limited proportion of retarding power under their own control—when the lines cannot be kept clear for them at stations at which they are not due to stop—and when they find it difficult to maintain their time-table speed, and at the same time to approach each and every signal in the course of their journeys with the requisite amount of caution, according to the severity of the gradients, the slipperiness of the rails, the proportion of break-power, and the positions of and view afforded by such signals.

These elements of confusion in working, far from being theoretical or imaginary, have too often been practically illustrated by lamentable accidents on various systems of railways; and it is in the endeavor to avoid such confusion that the modern recommendations and requirements of the Board of Trade and its officers have gradually, as the result of experience over a great number of years in observing these causes of accidents, grown to their present condition. The object of these recommendations and requirements is to substitute simplicity for such confusion, as a means of greater safety and efficiency in working. Simplicity in working has thus been obtained in a very great number of cases, and has yet to be obtained in many other cases. It consists, as regards signalmen, in affording to each signalman, by proper signal and point arrangements, complete control over the lines, sidings, and traffic at his post; in preventing him from making such mistakes in the handling of his levers as may lead to accidents—mistakes which the most careful men are liable to commit sooner or later, if they are not protected by locking apparatus, but which they are in a great measure prevented from making by such apparatus; in giving him sufficient warning of the approach of trains from different directions; in providing sufficient accommodation on lines and sidings to enable the main lines to be kept clear for the passenger trains. It consists, as regards the engine-drivers, in arranging that each shall have a distinct signal to look to for every necessary purpose, and that he shall have the means of properly obeying it, without any inducement to run risk in disobeying it. It cannot, of course be expected, even when the utmost simplicity in working is arrived at, that there will be no more accidents to deplore, because, unfortunately, human agency must still be relied on, and human agency must always be, as it has ever been, fallible. So long as engine-drivers are men, they will occasionally run past signals; so long as signalmen are human, they will occasionally make mistakes and misunderstand one another. Neither the block system nor locking apparatus will, as the author has frequently stated, be a panacea for preventing railway accidents altogether; nor can any other improvements be expected to have such an effect. But it is equally certain that the number of serious accidents may be very much reduced, and especially on certain railway systems, when all the improvements above referred to have been carried out. The risk of the mistakes of signalmen in working points and signals will have been in a great measure neutralized. Goods trains will not so much encumber the passenger lines, and will not be engaged in shunting on them, and crossing from one main line to another, when passenger trains are due; and this, of itself, by a simpler form of working, will tend to prevent a large proportion of accidents. De-

lays will thus be avoided also, both to passenger and to goods trains, and greater efficiency in working will be obtained. And this is no mere matter of speculation, because greater safety and efficiency have been and are obtained on those railways or portions of railways on which such improvements have already been introduced.

But it is necessary to consider next the arguments that are put forward in opposition to such improvements; and I may commence with the remarks which were addressed to the Institution of Civil Engineers by the President, on his recently taking the chair after his election to that office. When Mr. Harrison attributes to the author that he does not sufficiently appreciate the element of human frailty as contributing to accidents on railways, and leaves it to be understood that improved arrangements will not materially lessen the number of accidents and their serious results, the author would venture to reply that he estimates that cause of accident at no more and no less than has actually been found by the experience of many years to attach to it. There are, no doubt, as there always will be, accidents which occur from the inattention, mistakes, or neglect of officers or servants after all possible means have been provided for securing safety; but these form the smaller proportion, and in too many cases such mistakes or neglect arise in working under defective, and even glaringly defective arrangements; while, on the other hand, it is marvellous to observe for how long a period those officers and servants whose fallibility is thus considered to be underestimated frequently carry on their work under such defective arrangements without causing accidents of a serious character. Inefficient men are sometimes found also at most important posts. The wonder really is—and it is only fair to them plainly to say so—that the men who do the real practical work on the railways have made so few mistakes, when they have in so many cases been unprovided with proper means of performing their work. In order fully to prove the truth of this position, it would be necessary to adduce the experience of many years, which would occupy too much space here; but it will be sufficient for the present purpose to cite a few prominent cases in illustration of it, and some of them may be taken from the history of the North-Eastern Railway. The attention of that company appeared first to be seriously awakened to the necessity of interlocking point and signal levers on their existing lines, though they had for many years been necessarily doing it on their new lines, after the fatal accident at Thirsk, on the 9th of May, 1869, when a Scotch express train from the south ran through a pair of facing-points into a siding near the station, instead of pursuing its course along the main line. The signalman clearly could not have made the mistake which caused that accident if the lever by which the facing-points were worked had been interlocked with the levers for working the signals. He would in that case have been unable to lower his signals until he had first set the facing-points in the proper direction. Then, again, the collision at Brockley Whins, on the 6th of December, 1870, was one of the most disastrous in its results that ever happened on the North-Eastern Railway. In that case, an express up-passenger train and a down coal train, due to pass on opposite directions on two main lines without stopping, were turned into each other on a cross-over-road between these two lines. The collision was due, no doubt, to a mistake of the signalman, but under circumstances which would hardly be credited if they had not caused the accident. The signalman was provided with one lever for working together the two facing-points, one on each of those main lines, and thus with the means of the more easily turning the trains into one another and producing the accident; whilst that lever was not interlocked with the signal levers, so as to prevent him from lowering signals whilst the facing-points were set in this dangerous position. Five persons were killed, and fifty-nine were injured, as the result of this example of simplicity in construction and confusion in working. Turning to other railways, the fatal collision on the 29th of June, 1867, at the Walton Junction, on the main line of the London and North-Western Railway—the most costly collision, as regards the amount of compensation, that ever occurred on that railway, in which eight passengers lost their lives and seventy were injured—would have been prevented if the signals and points had been interlocked. The adoption of this precaution had been specially recommended for the same junction by the author, on the occasion of a previous collision on the 1st of January, 1862, in the words quoted near the commencement of

the present paper. Then, again, there was the collision at Kirtlebridge, in 1872, the worst example on the Caledonian Railway, in which eleven persons were killed and fifteen were injured, and which will, it is said, when all claims have been settled, cost the company about £50,000. In this latter case, the station-master himself turned a shunting goods train across into the way of a night express train from London for Scotland, after a signalman at a distance from him had lowered the signals to allow it to pass. But the station-master would not have made this fatal mistake, and it could not have been made at all if the points had been worked from a cabin, and if the lever for working them had been interlocked with signal levers. These are a few instances which must, it is true, be set down to mistakes of officers or servants, but in which this element of human fallibility might and would have been completely neutralized if only points and signals had been interlocked with one another, and if thus simplicity had been substituted for confusion in working.

Another recent illustration of the arguments employed against such improvements in railway working is contained in the half-yearly speeches of Sir Edward Watkin, and, coming from so practical an authority, they ought to be worthy of special attention. In addressing the shareholders of the Manchester, Sheffield, and Lincolnshire Railway, at Manchester, on the 28th January, 1874, Sir Edward Watkin is reported in the "Railway News" to have said that the Board of Trade "assumed that men were infallible instead of fallible; that they were always awake and attentive, and that they never could by any possibility make a mistake." Now it will be at once apparent that if the Board of Trade had any such conviction its officers would not have thought it necessary, for instance, to require that signal levers and point levers should be interlocked with one another, because if men were really infallible, they would never pull over the wrong lever, and in that case the serious accidents above cited would, in fact, never have occurred. It is precisely because human agents are fallible that the various precautions referred to are required to counteract as far as possible the element of such fallibility; and it is for that reason that locking and other arrangements become necessary. It is hardly necessary to say that Sir Edward Watkin has no warrant for making such an assertion, which, indeed, he himself partially refuted—according to the same newspaper—at the half-yearly meeting, on the following day, of the South-Eastern Railway Company. He then made a very different allegation in saying:—"But where the Board of Trade's heresy is, is in believing that by the adoption of mechanical appliances you can insure almost absolute safety." So that the Board of Trade has two heresies—one in assuming the men to be infallible, and an opposite one in trusting to mechanical appliances. But he goes on himself to express confidence in mechanism:—

"I say it is heresy because it overlooks the fact that you have to work without military discipline your 8,000 or 10,000 men who are fallible. It is the mistakes of those men which cause the accidents, and not the failure of mechanism or deficiencies in the strength or endurance of material."

And again:

"My notion of railway working is simplicity. These things increase complication. The Board of Trade requirements tend to make the thing complex, to make it difficult, and to multiply the causes which lead to error; and I think myself, if you will take the average of ten years after we have got all these new-fangled things into operation, it will be shown that the old, simple arrangements of Stephenson, Brunel, and Locke are best; and, after all our experience, we may have to come back to the simple way of working, and to put many of these new-fangled things into the fire."

The author recently heard of an observation even more extraordinary than the above, which was addressed, not long since, by an aged Field-Marshal to a still more aged retired Lord Chancellor, as they were walking together at Hampton Court, and which was related to him by a friend who was with them. In the midst of earnest conversation in a loud tone—for they are both rather deaf—the Field-Marshal suddenly stopped, and thumping his umbrella violently on the ground, said impressively, with evident reference to a bygone period, "When I went to see the Dook at Walmer, the Dook said that railways would never answer in this country; and, you see, here's this Wigan accident. The Dook was right." This sentiment is, in one sense, on a par with Sir Edward Watkin's proposal to "put many of these new-fangled things into the fire," and to return to the sim-

plicity of older days. Exactly to what period of simplicity he would revert he does not point out; whether to the days of no signals at all, and to the system of the fireman jumping off the engine to push over the switches, without the aid of a lever; or to any particular epoch between that time and the present, he does not specify. But, seriously, can he believe, as chairman of the South-Eastern and the Metropolitan Railways, that by putting the apparatus—complicated, no doubt, in construction, but simple in working, as compared with the duties to be performed—into the fire; by doing away with the locking apparatus and the block system at Charing Cross and Cannon Street, and at the various complicated stations on the Metropolitan Railway, with trains following each other and crossing the path of each other within periods numbered sometimes by minutes and sometimes by seconds, that the traffic could be carried on at all? He would find that not one day, nay, in some places, not one hour, would pass without a serious accident and a complete block to the traffic. And, indeed, the author has had occasion himself to inquire into two accidents which have so occurred, during a temporary want of the apparatus, on the occasion of alterations or repairs.

Sir Edward Watkin's remarks were anything but complimentary to the common sense of his shareholders, and they were an insult to the memory of the illustrious engineers whose honored names he dragged into such an argument. They would never have proposed to work the traffic of the present day with the simple arrangements of former times. Speaking specially of the block system he further says:

"It is very good, but it has a weakness I have often pointed out, namely, that it leads on the part of our servants to too great reliance on the machinery, and a weakening of the reliance on themselves."

And he takes credit for the South-Eastern Company—as other chairmen have done for other companies—for having been the first to adopt his system. He says:

"But if there is any credit to be taken for the block system, I am here to tell you that the credit belongs to you, for the first railway in England (before the Board of Trade found out that there was any good in it) that adopted the block system was the South-Eastern, and the first railway that completed their line was the South-Eastern. We got no hints from the Board of Trade. We acted on our experience, and it has been a valuable advantage (always with the drawback I have mentioned) in conducing to the safety and regularity of our work."

It is hardly, then, the apparatus connected with the block system which Sir Edward Watkin would propose to put into the fire. Is it the locking apparatus that he would wish to commit to the flames? Speaking at the South-Eastern meeting, he says, it will be observed, "we got no hints from the board of trade." Speaking at the Metropolitan meeting, in regard to a collision under the block system, he attributes it to the Board of Trade meddling, as I shall presently show. But, in reality, the same hints and the same meddling applied to both railways equally, excepting that there were additional hints in the case of the South-Eastern Railway, which may be quoted, both as opening up another interesting subject for discussion, and as showing the risk that an officer of the Board of Trade may incur even when invited and doing his best to assist a company presided over by a chairman, who, like Sir Edward Watkin, attributes accidents which arise from a mistake of his signalman to the Board of Trade. Some months before the Charing-Cross Railway was open for trafic, the author was asked by the South-Eastern Company to make a preliminary inspection of it, and to confer with the officers of that company as to the best mode of dealing with the signal and working arrangements, and he had, as he always has, great pleasure in being of any use in that respect. Besides the general arrangements, which were agreed upon without much difficulty, an important question arose, in regard to the working of the block system. It was proposed by the company to work the Charing-cross line by bells only, as other parts of the South-Eastern Railway were worked, without block instruments. But the author ventured to dissent from that proposal, and to express the opinion that, considering the importance of the line, and the nature of the traffic which it was likely to accommodate, it was absolutely necessary to provide visual as well as audible instruments, to give the signalmen, in fact, the advantage of a record before their eyes as to the conditions of each block-length—whether it was obstructed or whether it was clear—in place of trusting to their memories as to the last signal

which they received or transmitted on their bells or gongs. The author stated, in fact, that he would be unable otherwise to recommend the Board of Trade to sanction the opening of the line. The talented electrical superintendent of that company accordingly contrived and provided, before the opening of the line, the minaiture semaphore signals which are working in the cabins; and the safety of the line has been probably due in some respect to the "hint" on which the company thus acted. And this hint may further be supposed to have been considered valuable, inasmuch as the use of Mr. Walker's miniature semaphore has since been extended to all other portions of the South-Eastern Railway. But if any accident had occurred through the failure of, or in working those instruments, ti would, of course, have been open to the chairman to attribute it to Board of Trade meddling, as he did, publicly, the collision which occurred on the Metropolitan Railway, between the Gloucester-road and the Kensington High-street stations, on the 29th of August last. In that case a disabled train proceeding from the Mansion House Station to the Edgware-road Station came to a stand in a tunnel after passing Gloucester-road; and the signalman at the High-street Station, when an unusual length of time had elapsed since he received notice of it, asked on his speaking trumpet, "Is train coming?" to which the Gloucester-road signalman replied, "I have not received line clear for last train." The signalman at the High-street, fancying he must have forgotten to give "line clear," did so, and a second train was thus allowed to enter the block length before the first train had passed out of it. Sir Edward Watkin remarked upon this at the half-year meeting of the Metripolitan Railway on the 22d of January, 1874, as reported in the *Railway News* of the 24th of January:

"Now this accident, the first of the kind which has occurred, I think, during a period of twelve years' working, ought to be called—as many accidents out to be called—a Board of Trade accident."

And he proceeded to argue that because the Board of Trade recommended in their general list of recommendations—for it was not an absolute requirement—speaking instruments as well as block instruments in the cabins, and because the signalman had, in calling attention and replying on the speaking instruments, committed this error, therefore the accident was, as he put it, "the consequence of the Board of Trade meddling." There was, however, another recommendation—that record-books should be kept also in the cabins; and this had not, it appeared, been complied with in the Gloucester-road cabin. Whenever an accident occurs at any place where every precaution has been taken to avoid it—and such accidents must be expected occasionally to occur— and where all the requirements and recommendations of the Board of Trade have been complied with, it will of course be open to any chairman of a company, so disposed, to attribute such accident to Board of Trade meddling, and to call it a Board of Trade accident. But in this particular instance the signal-man might have committed the mistake in question without speaking instruments at all. The recommendation with regard to the adoption of speaking instruments in addition to block instruments is contained in clause 7, under the heading of "Precautions Recommended in the Working of Railways," and is as follows:

"When a line is worked by telegraph, the telegraph huts should be commodious, and should be supplied with clocks with record-books, with a separate needle for signaling the trains on each line of rails, and with an extra needle for other necessary communications between the signalmen."

It was adopted because signalmen had been found to be making private signals to one another on their block instruments or their bells, "shaking each other up," as they termed it, by shaking the needles and so on. The recommendation has, in very many cases, not been complied with, and it will be an interesting subject for discussion whether and how far it should be acted on, as well as how far it may be considered desirable to depend upon bells alone without block instruments. Speaking instruments are, indeed, absolutely necessary in many cases, when it is considered requisite to afford information from distant stations of the running of fast non-stopping trains—whether they are keeping time, or whether and how much they are behind time. They are required in other cases for the transmission of messages on the company's service in regard to the working of the line in various respects. In the absence of them, the block regulations of some companies prescribe codes of signals

by beats on the telegraph bells; and the number of beats required for such purposes mount up, as already stated, to 14 or 15. It is an important question to consider whether the signalmen may not make mistakes in counting so many beats on the bells more easily than in the use of speaking instruments. Sir Edward Watkin's proposal in the same speech was to send a man in place of using a speaking instrument, and was thus expressed:

"The idea of the Board of Trade, no doubt, was this: that if anything took place in the way of blocking, the signalman should be able to ascertain what it was, instead of pursuing the old-fashioned plan, that when there was a block somebody should be sent to see what it was."

But no man would in this have been sent running from the Gloucester-road signal cabin to the High-street signal cabin, even if there had been no speaking instruments in the cabins; and at all events the Board of Trade have never made any objection to Sir Edward Watkin's employing men in that capacity if he thinks proper, and finds it compatible with the working of the traffic on the Metropolitan Railway to do so. It is the more necessary to make the above observations because Mr. Forbes, the chairman of the Metropolitan District Railway, is reported to have echoed in some degree the sentiments of Sir Edward Watkin in regard to the accident on their joint line. According to the *Railway Times* of the 14th of February, 1874, Mr. Forbes is reported to have said, at the half-yearly meeting, on the previous Tuesday, of the Metropolitan District Railway:

"The item of compensation had been 5000*l.* extra in the half-year, with which they had really nothing to do. The accident was caused by one Metropolitan train running into another Metropolitan train, and they had to pay one-third of the cost under the agreement with that company. He complained that under the direction of the Board of Trade they were obliged to use apparatus that had caused accidents and had entailed a loss of 18,000*l.* in damages, which he thought very hard indeed.

It would be interesting to learn from the general manager of the Metropolitan and the manager of the District Railway, whether now, after the experience of that accident, they are prepared to remove the speaking instruments from all the signal cabins, and whether they could carry on the working of the line without them. Unless they can come forward and tell us that they are prepared to adopt this measure—which, if they consider it expedient, there is nothing to prevent them from doing—it must be admitted that the remarks of Sir Edward Watkin and Mr. Forbes on the subject were more ingenius than ingenuous; and the author contends that they were, in any case, in the highest degree unjustifiable.

Fully to expose the injustice and the nature of the accusation thus made by Sir Edward Watkin and Mr. Forbes against the Board of Trade for causing this accident by meddling, because one of their recommendations is that there shall be "an extra needle for other necessary communications between the signalmen," it is right, however, further to point out that the printed regulations for signalmen on the Metropolitan Railway provide for the use of speaking instruments, two in number at terminal, and three in number at intermediate stations, that there are six in the cabin in which the mistake was made, and that the signalmen are directed to use these speaking instruments when the disc instruments are out of order, or the bells fail to ring.

The following are the regulations referred to, extracted from "The General Rules and Regulations to be observed by the officers and servants employed by the Metropolitan Railway Company:

"118. The station at each end of the line is provided with two train signalling instruments, one for the up-train service and one for the down-train service, and a telegraph bell instrument; two speaking instruments are also provided, one to communicate only with the next station, and the other instrument for communication with all stations.

"119. The intermediate stations and junctions are each provided with four train signalling instruments, one for up-trains and one for down-trains in one direction, and one for up-trains, and one for down-trains in the opposite direction, with two bell instruments; three speaking instruments are also supplied, one for use to and from the station on either side, and the through instrument, by which each station is in communication with every other.

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"131. Should the disc instrument be out of order, or the bells fail to ring, the speaking instrument must be used for the purpose of signalling the trains."

And the following is a regulation for signalmen, to a similar effect, from the printed book of rules for the Metropolitan District Railway:

"90. Each station has an independent speaking instrument to the next station on the either side. There is also a through speaking instrument, by which each station is in communication with every other."

The rule-books of these two companies thus provide for speaking instruments in the cabins, in excess of the Board of Trade recommendation; and it is due to the companies to suppose that they do not supply more instruments than they find in practice to be necessary. But it is anything but justifiable in the chairman to represent that an accident occuring in the use of instruments provided for their own purposes has resulted from their being forced to obey a Board of Trade recommendation, contrary to their own convictions; and especially when there are signal cabins on other lines where the recommendation in question is not complied with at all. The railway companies have not, indeed, always been in the habit of so implicitly carrying out the recommendations made to them by the Board of Trade as might be inferred from the accusation referred to.

Mr. Forbes, also at the half-yearly meeting of the London, Chatham, and Dover Railway Company—as reported in the *Railway Times* of the 14th of February, 1874, "protested against the duplicate management which was being instituted by the Board of Trade, for it was this it amounted to, and the department was placing more faith in machinery than in men. This was really deteriorating the men, for they relaxed their watchfulness in the trust in machinery, and were trapped into a security which had led to two accidents on the line."

Mr. Forbes does not state what accidents he particularly refers to, or by what special machinery the men are trapped into security; and it is therefore impossible at present to reply in detail to his allegations; but if he will be more specific on these points it will add to the interest of the discussion, and his charge, shall be fairly met. Meanwhile, the author is quite ready to admit, and has often stated, that there may be a tendency in the block system to engender confidence in engine drivers, guards, and all connected with it, as regards the safety of these trains from collision; and that such confidence is justified by the results of its working. But while it is only natural that engine drivers should have less apprehension of obstruction from trains, it must be remembered that there are still public road crossings, occupation crossings, the liability to find plate-layers at work, or vehicles thrown from another line foul of that on which they are traveling, as well as other causes, requiring them to look out. The experience of block working hitherto has not justified the apprehension which has, at times, been expressed of greater danger being incurred, and more serious accidents being caused, as the result of undue confidence thus engendered. Instances may, it is true, be adduced of engine drivers running past signals, or of signalmen making mistakes, under the block system. But many more instances may be brought forward of similar causes of accident where the block system has not been in force. The great balance of actual experience, up to the present time, has shown that there is more risk of inattention, mistakes, or neglect on the part of officers and servants in railway working when they are constantly compelled to work with insufficient appliances and accommodation, and are thus trained, so to speak, to dangerous practices, than when they are provided with the means of carrying on their work in a safe and proper manner; and good discipline, which is, after all, and in any case, a most important element, can then better be maintained. And the memorial and opinions already referred to of the engine drivers on the North-Eastern and London, and North-Western Railways, are illustrations of the natural desire which these men must, more than any others feel to be afforded the means of carrying on their daily work under safe conditions, with sufficient warnings of obstructions, and ample means of obeying signals.

As an illustration of the necessity for block working combined with more accommodation for the conduct of traffic, and of working of railway traffic under difficulties, the author cannot do better than refer to the circumstances of a collision that occurred on the 13th of December last, near Bolton, on the Lancashire and Yorkshire Railway. On that occasion, a down passenger train from Manchester to Fleetwood overtook,

whilst running, and came into collision with, an empty wagon train, in a misty state of atmosphere, a mile and a quarter after leaving Bolton; and a portion of the wreck having been thrown upon the other—the up line—it was immediately afterwards run into by an up passenger train from Southport for Manchester. In this double collision, forty-two passengers and six servants of the company were injured or shaken. There are two signal cabins, 194 yards apart, called the Bullfield upper and lower cabins, on the further side of the Bullfield tunnel from Bolton; and the signalmen in those cabins, who had, as usual, exhibited caution signals only from their hand-lamps, were dismissed from the company's service for not obeying the regulations, which required them to show a danger signal for five minutes and a caution signal for five minutes longer after the passage of the empty wagon train to any following down passenger or other train. But it turned out on inquiry, that it had not been the practice at those cabins, at all events for eight years, to obey those regulations—that the signalmen did just what they were in the habit of doing, and what other signalmen working in those cabins would have done; and that the traffic could not have been carried on in conformity with such regulations. One of the signalmen further pointed out that he could not be expected to keep the trains five minutes apart when they timed to start from Bolton within two and three minutes of one another. A relieving signalmen, not concerned in the accident, stated that he would have worked in the same manner, and himself have been dismissed from the service of the company, if the accident had happened an hour later; and he further stated that when he left his cabin to give his evidence, there were five engines—which turned out on enumeration to be six—on one main line, and three on the other main line, of which one was shunting in and out of the sidings at each side, and the others were waiting to shunt or to pass. The engine-driver of the passenger train, who had complained before leaving Bolton of the empty wagon train having been sent away in front of him, was told in reply that it could not be helped. Now there were no "new-fangled things," at these cabins. They were stated to be twenty years old, with such apparatus as they contained; and there was certainly nothing in their appearance to lead to a contrary opinion. The author ventured to think that less confusion and more simplicity in dealing with the traffic might be obtained by the addition of extra lines and sidings, and by the construction of improved cabins with modern apparatus in connection with them, and also by the extension of the block system (at present in force for the Bullfield tunnel only) to the portion of the line on which the collision occurred. The caution, the presence of mind, and the self reliance of the officers and servants of the company must, certainly, have been developed to the utmost in the working of this traffic; but not with with a satisfactory result, either to the passengers and servants of the company who were injured, or to the two signalmen—of good previous character—who lost their situations for doing their duty to the best of their power, as they had been trained to do it, as they had always done it, and as they were compelled to do it. The neglect of fallible servants will, no doubt, be considered by some to be a cause ot this accident; but it is not essential to railway working that frail human nature should be employed under such conditions; and the author would commend this case—one of the more recent which it had been his duty to investigate—to the serious considerations of those who, in opposing what are called "modern requirements" on railways, like Mr. Harrison and Sir Edward Watkin, are inclined to lay too much stress upon human frailty as the cause of accident, to decry the means and appliances by which that element of constant risk may be in a great measure neutralized, and to leave out of consideration the difficulties—the disadvantages, and the defective or insufficient arrangements under which the officers and servants of railway companies are frequently compelled to work. The opponents of modern improvements, which are thus designated as "new fangled things," are, in fact, not now found so much amongst the officers and men who have the practical working of them. Such officers and men, on finding out the value of them for their own protection, and for real simplicity and safety in working the traffic, are only too glad to obtain them, and are only anxious that their operation should be extended. The opposition to them comes mainly from certain chairmen and general managers of railways and others whose practical experience was gained in former years before many of the improvements now so suc-

cessfully employed were available, and under different circumstances of traffic; and from gentlemen such as the President of the Institution of Civil Engineers, who having some time since retired, as he tells us in his address, from the active work of railways, has not yet realized the benefits which such improvements confer. Many who were once opponents have now become firm believers, and, sooner or later, the true difference in such matters between simplicity in construction and simplicity in working will, the author believes, be all but universally understood and admitted.

Since the above was written, another eminent and practical railway chairman has made use of arguments and expressions which can hardly, in such a paper, be passed over without notice. Sir Daniel Gooch is reported in the *Railway Times* to have said, at the last half-yearly meeting of the Great Western Railway Company, on the 4th of March:

"We complain of the mechanical arrangements and contrivances, and different things that are forced upon railways contrary to the opinion of the railway engineers and officers who are responsible for working the railways, and who have had experience to enable them to judge of the efficiency or otherwies of these contrivances. Therefore we say, and say it very strongly, that these contrivances of the Board of Trade, to the extent to which they are forced upon us, are increasing the danger of our railways."

And again:

"Undoubtedly our mechanical contrivances are very ingenius and clever, but they are not equal to the mechanical contrivances and appliances provided by a higher power; therefore I have much more confidence in a well-trained pointsman at his post than in any mechanical appliances designed to take his place."

These quotations would seem to convey the ideas: 1. That railway companies ought to abolish locking apparatus and trust to Providence; 2. That the Board of Trade is seeking to supplant well-trained pointsmen, and to emply mechanical contrivances and appliances in place of them; 3. That the danger of railway working is being increased by a number of things—though it is not stated what things—which the Board of Trade is forcing upon railway companies. Sir Daniel Gooch no doubt honestly feels what he so pithily expresses; but he certainly exhibits an extraordinary misapprehension of the principles by which all the action of the Board of Trade has been guided. And, indeed Mr. Harrison made a complaint in the opposite direction, namely, that the requirements of the Board of Trade would necessitate the employment of a much greater number of signalmen, and thus lead to increase risk. Placing side by side the allegations of the four eminent gentlemen who are the chief complainants, it will be observed Sir Edward Watkin cuses the Board of Trade of two heresies—one, in considering the men infallible and the other in expecting too much from machinery; Mr. Forbes says that the Board of Trade mistake is in trusting to machinery rather than to men; Sir Daniel Gooch prefers to trust in well-trained pointsmen, which he looks upon as the better contrivances of a higher power; and Mr. Harrison complains—with special reference to the block system—that too many of these men are required. The truth of the matter is that the Board of Trade desires, not only to see well-trained signalmen employed, but also that they shall be provided with apparatus that shall enable them to work with the utmost possible simplicity, and shall neutralize as far as possible the mistakes that otherwise the best of men are liable—nay, are almost certain, sooner or later, in the course of years of working to commit; and wishes, further, to see their numbers increased only so far as is necessary for the proper performance of their duties, for affording due warning to the engine drivers, and for enabling the traffic to be worked in the simplest, best, and safest manner.

But the present is an admirable opportunity for these, or any other gentlemen, to come forward, and to state specifically what mechanical contrivances ought, as they think to be dispensed with, and what are in their opinion admissible. If the Board of Trade is proceeding on a wrong basis, in whole or in part, let them point out precisely what are its errors. The only object is to increase the safety and efficiency of railway working; and that object may, apparently, best be secured by more simplicity and less confusion in working, on the principles stated in the present paper. There has been ample experience as to the causes by which railway accidents have been produced, as to the defects which they have disclosed in construction and working, and as to the remedies by which they may be and have been avoided. The author has

labored anxiously and earnestly, by analysing from year to year the results of that experience, to afford the best means of judging—to any one who will take the trouble to study those results—not of the working of any one line, but of all the railways in the United Kingdom; and he will feel deeply grateful to any one who will correct him in any of the conclusions at which he has arrived, or point out to him any other mode by which the safety and efficiency of railway working may be better secured. Under no system can perfect safety be obtained—as he is too well aware—but confidence in a higher power, as it is expressed by Sir Daniel Gooch, can only with propriety be entertained after all reasonably means have been exhausted.

To sum up the whole case, it is necessary, in railway working, to deal with men and mechanism. Men are fallible, and mechanism may fail. The complications of railway construction and traffic have increased enormously, and are still increasing. At some points the lines, the sidings, and the crossings are so numerous, and the traffic is so constant, that the employment of the best means and appliances is unavoidable. In other localities, of severe gradients or obstructed view, or when greater danger is otherwise incurred, similar means and appliances are also indispensable. These points and localities become more and more numerous, and ample experience has now been obtained as to the most efficient modes of working. The result of that experience has plainly demonstrated that mistakes and accidents may best be avoided, and efficiency of working may best be obtained: 1. By judicious selection, and careful training of the men employed, and especially—in a safety point of view—of engine drivers and signalmen. 2. By providing those men with reasonable and necessary apparatus and accommodation for the proper performance of their duties. 3. By maintaining good discipline amongst them, which is only feasible when proper means and accommodation are provided, when proper modes of working are adopted, and when it is possible for them to carry out in practice the rules and regulations furnished for their guidance.

These three desiderata include the provision of fixed signals in sufficient number to enable the signalmen to afford due warning in each case in which warning is required to the engine drivers, and to enable the engine drivers clearly to understand the warnings so given to them. They include the supply of locking and other apparatus, which has been proved to act efficiently in preventing or neutralizing the mistakes, in the working of points and signals, which the best of men are otherwise, sooner or later, almost certain to commit. They include the addition of sufficient lines and sidings to enable the traffic to be properly worked—without goods or mineral trains constantly obstructing the passenger lines—without the main lines being blocked when fast through trains are due or may be expected—without excessive delay to slow or goods trains in waiting for fast or passenger train to pass—without stopping trains being shunted from one main line to another, to allow fast trains to pass them—without habitual unpunctuality. They include the necessary apparatus for enabling intervals of space to be preserved between running trains, and the proper arrangement and working of such apparatus, with the careful adaptation of it to local circumstances. They include the provision of ample retarding power in the trains, applicable at the will of the engine driver, to enable him to obey the signals which he receives, and to bring his train to a stand within a reasonable distance. They include, in fine, all those things which contribute to simplicity, and which tend to the avoidance of that great cause of extravagance, inefficiency and danger—confusion in railway working.

COMPOUND v. SINGLE CYLINDER.

From the "English Mechanic."

The superior economy of fuel in the ordinary form of the compound marine engine is generally considered as a fact so thoroughly establishd that many regard a man who has a contrary opinion as one ignorant of what has been accomplished. But the heretic finds comfort in knowing that there are men of very superior minds to whom these heretical opinions are orthordox.

Any one who has doubts, and wishes to investigate the matter will be rather disheartened by a few reflections which will be naturally suggested :—e.g., if the two principles are to be compared the conditions of the trial are such as to render the search for reliable data discouraging in the last degree. Suppose we were fortunate enough to find two ships of exactly the same build, engined, the one with compound and the other with single cylinder engines, the common parts of which being exactly alike, using the same steam pressure and ratio of expansion, the ships fitted with the same propellers and boilers of equal evaporative powers. Having found such ships, how are the trials to be obtained ? They must be conducted by good theoretical, as well practical, men —such as will not in the majority of cases, be found in charge, and the trials to be valuable must extend over very lengthened periods.

For myself, I know of no single trial which will satisfy these conditions.

All that remains is to reason as we best can upon what facts and information we can obtain.

In the first place, then, my argument demands that I must say a few words respecting the two kinds of compound marine-engines, viz. The Hornblower or Woolf, which, during expansion, exhausts directly from one cylinder into the other; and the common form exhausting from the small cylinder into a receiver. With respect to the first the Woolf, I think few will say that in economy of fuel it is not, at least, *equal* to the Receiver principle. But as even this may be questioned I shall first state that Messrs. Randolf and Elder's first patent (specification No. 177, 1853) was for improvments in the Woolf form, the cranks being placed opposite each other; and that the Receiver was first introduced, *as a necessary evil*, for the more convenient handling of the engines, the cranks being 90° apart;—and then I may call attention to the fact that some of our most successful engines in point of economy of fuel are those having no receiver ; or those the more nearly resembling Woolf's principle.

In support of this I beg to refer to the evidence of Mr. Wright, the Admiralty Superintendent of Machinery, before the Commission on Designs for Ships of War 17th May, 1873: —" 3,536. Question : Supposing you did away with the jacket, would you still keep the receiver itself ? Answer : I think on the whole we are in a measure obliged to do so at present, for convenience in handling the engines. In point of economy, I presume it would be better if the steam could be sent in direct from one cylinder to the other." Again, the line of steamers known as " Holt's Line" are looked upon in point of economy second to none, and those engines are, in fact, Woolf's principle. The performance of the *Arequipa*, which in economy heads a list showing the average consumption of coal by steamships with compound engines in long sea voyages; the consumption is 1.7lb. per I. H. P. per hour, and the engines are by Randolf and Elder (Woolf). See " Proceedings of the Institution of Mechanical Engineers," July, 1872. Liverpool Meeting, part I., p. 158. Now, if it is granted, as I think it must be that compound engines of the Hornblower or Woolf type are as economical as the common marine engine using a receiver, an important axiom is admitted; and as I am dealing with the question of economy of fuel alone, it immediately follows that I can compare the economocal performance of the compound with the single cylinder Cornish engine, and, by so doing, decide the respective merits of the compound and single cylinder marine principles. If this mode of reasoning is fair, I at once get rid of all uncertainty and dfficulties, and can proceed with my argument upon data which is undeniable.

The foundation of this data is the Cornish Engine Reports, which commenced in the early part of Watt's career, and are at this moment in progress. These reports show during the whole of this period the duty in actual foot pounds of the engines reported; and the perfection of the Cornish engine is chiefly due to the emulation created by them, not only in the proprieters of the mines, but even in the firemen and boys.

Armstrong, in his treatise upon boilers, has questioned the accuracy of them, but according to Pole, the injustice of this attack is now generally acknowledged. Wickstead, in 1835, visited Cornwall to inspect the engines there. An account of his visit is given in his work, and in the Transactions of the Institution of Civil Engineers. " He inspected several en-

gines, and the result of his examination was the perfect conviction of the accuracy of the reports given."

No person could possibly render more reliable information upon the subject than the reporters themselves, and it is from Lean's Historical Statement of the Steam Engine in Cornwall (written by a man who for many years acted in that capacity), I shall make the following extracts:

In the latter part of 1814 Woolf's engine was first introduced into Cornwall, at Wheal Abraham, and in October of that year, it was first reported, its duty being 34 millions. Soon after a defect was discovered, and the duty was advanced to 52·3 millions.

In 1816 Jeffree and Gribble erected a new single cylinder engine at Dolcoath which did 40 millions. Still Woolf's engines maintained the first place, the duty performed by that at Wheal Abraham was 56·9 millions.

In 1820 Woolf's engines with the double cylinders, owing to the difficulty of keeping them in repair, had fallen to the average of the best simple engines, *and after this period began to be disused in the mines.* Here it must not be forgotten that Woolf had a reputation for superior excellence of workmanship. In December, 1827, an important trial of Woolf's principle took place, at Wheal Fortune. The trial lasted 26 hours 30 minutes: duty 63,663,473. The report is signed by nine persons. Early in 1828 Woolf's engines at Consolidated Mines head the list with a duty 93·7 millions. The engine at Wheal Towan, by Gorse, comes next: duty 60 millions. Another trial in the same year of engine by Gorse, at Wheal Fortune (boiler pressure 40lb.), duty 87,209,662. The report is signed by Sims and nine others.

It is well to note that these trials were conducted by men of opposite interests, who questioned the accuracy of the reports: here the engine is by Gorse, and Sims conducts the trial, and signs the report.

The following extract I have made from the Report for 1828. I have selected a few of the best.

Wheal Towan	Gorse	87	mills.
" Hope		7.48	"
Consols	Woolf	67.6	"
Birmer Downs	Griger & Thomas,	63.5	"
Consols	Woolf	61.7	"

In 1835 a trial of Austin's steam-engine of 80in. cylinder, at the Fowley Consols and Lanescot Mines, (Oct. 22-23, 1835), with steam from 36½ to 45lb., gave a duty of 125,095,713lb. with one bushel of coals of 94lb. The trial lasted 24 hours and 27 mins. This was a very carefully conducted trial, and was well authenticated by many important witnesses whose names are appended.

In the same year I find the following duty recorded:—

	Engine	Duty
Consolidated Mines	Woolf's	55,776,173
Wheal Bor	"	47,541,497
Consolidated Mines	Taylor's	71,281,509
"	Davy's	76,128,086
"	Shear's	61,108,450
Wheal, Darlington		75,133,483

The above-mentioned single cylinder engines are only a portion of those performing a higher duty than Woolf's, and have not been selected by me.

In 1836 Wheal Darlington engine heads the list with 94·4 millions; Woolf's engines are not given, so that their duty may be considered under 60 millions; it being the practice to expunge engines of low duty from the reports, in order that the average duty might not suffer; for a low average duty, it was supposed, would have an injurious effect.

From the "Journal of the Royal Institution of Cornwall," Vol. XIII., 1872, we learn that the—"The system of combined cylinders modified by placing one above the other, and admitting steam above the smaller and upper, and allowing it to expand thence beneath the larger and lower piston, was introduced for a third time at Carn Brea and great S. George, by Jas. Sims; but notwithstanding the high duty of 88 to 100 millions was reported this form of engine again failed to secure favor, and its use has been discontinued."

In addition to this I have learned from Cornwall, within the last few months, that no double cylinder engines are now reported in the county, and that several combined cylinder engines have been replaced by single engines. There is no question about the object of Woolf's Patent, viz., to introduce high steam pressures; and it appears from what I learn perfectly certain that he often used much higher pressure than those now common in Cornwall, and yet with his superior work and steam-pressures he never obtained so high

a duty as that exhibited by the single cylinder system, with a steam-pressure varying between 30 and 40lb. above the atmosphere!

This is an argument complete in itself, and will, if honestly considered, I am sure, be thought a sufficient excuse for thinking that there are good grounds for at least *suspecting* the much talked-of superior economy of the compound marine engine.

But we can go further than this with the argument! In the "Encyclopædia Britannica" for 1810, under article "Steam Engine," will be found a calculation either by Watt himself or Dr. Robison under the eye of Watt, showing that no possible advantage could be obtained from the use of Hornblower's engine, and bearing in mind that this engine was constructed to work at the steam pressures then in use (Woolf's being the same principle adapted for the use of higher pressures) it will be at once conceded that the proof given by Watt, or Dr. Robison, is that when steam of the same pressure is used the compound has no superiority over the single cylinder; indeed this much will be found in the following transcript:—

"We have done service to the public in showing that this engine, so costly and so difficult in its construction, is no way superior in power to Mr. Watt's simple method of stopping the steam. It is even inferior, because there must be a condensation in the communicating passages."

And turning from the Pumping Engine to the marine type, we find that where the steam has been at the same pressure, the economy has been the same: take the trial of the *Swinger's* and *Gohawk*, see the *Times* of May, 1872.

I have now said enough, I trust, to show that if the compound marine engine is superior to the single cylinder when using the same steam pressure and ratio of expansion that *the superiority does not lie in the economy of fuel*; but if space is allowed me I should like to go a little further, and to say a few words upon this question. Is it necessary to use steam of so high a pressure as 60lb.? for although I certainly think that, if proper regard be paid to the construction of the engine, and by using a fly-wheel, the single cylinder is as good for marine purposes with high pressure as the compound; yet there is this consideration; A compound engine, to effect a high rate of expansion, may be the cheaper machine of the two, for in it no expansion gear is considered necessary, but in the single cylinder a double expansion gear is required, and in addition, perhaps a fly-wheel. But suppose that for ordinary merchant ships one cylinder only with a fly-wheel were proved to work very well, how would the comparisons between the two principles stand then? There can be no question about the cost and economy of space being greatly in favour of the simple type. And why cannot this be done? We know that the Holt Line of steamers use engines in which the two cylinders work upon a single crank, and I have been personally informed that those engines are handled with the greatest ease. Land engines are generally on this plan and they are stopped and started in comparison, much oftener than the engines at sea.

But it is a point worthy of careful consideration whether steam of a higher boiler pressure than 35lb. is necessary to effect the same economy as that of 60lb. In the Cornish engines we have seen that the greatest duty was given by that (35lb.)mean. Cramp ton in experiments conducted by him, where the actual duty was obtained, found that nothing was gained by working over that pressure. Mr. Hawksley's opinion also confirms that view. And if it is a fact that a boiler pressure of 30lb. or 35lb. above the atmosphere will give the greatest economy, the argument for the use of one cylinder only is vastly strengthened and it is to be regretted that no really scientific experiments have been tried to decide the question, which might easily be done by taking a compound marine engine and an engine of a single cylinder of the same power, with the common parts exactly similar, arranged to work from the same boiler; to use the same condenser, and to work the same pump or friction brake—then by trying them, say for a week each, alternately, until a definite result, both as to economy and equability of motion were obtained. And I cannot close without saying that I consider it a monstrous disgrace to a nation like England that such experiments have not been made, instead of wasting time in inquiries from which no definite good seems to accrue.

THE FREEBOARD OF MERCHANT SHIPS.

From "Engineering."

The question of the freeboard of merchant vessels, which has for many years been more or less under discussion to very little purpose, has, within the past twelve months or so, been the subject of renewed interest, and has given rise to vigorous thought and action, which have together made a decided and permanent advance towards a solution of the question. The powerful pressure brought to bear upon the legislature to fix by law a hard and fast load line for all vessels has done much good in proving, by the exhaustive examination of the case which ensued, that it would be impossible to fix a hard and fast maximum load line without doing one of two things, viz., to encourage and countenance overloading by law, or to seriously hamper and interfere with the safe carrying trade of the world, with the prospect of placing English shipowners at a ruinous disadvantage in some trades, compared with foreigners.

It is almost obvious, but it has required a vast amount of argument to prove it to some, that a vessel running across the Channel in the middle of summer, could carry a certain cargo with less fear of foundering, than she could cross the Atlantic in the middle of winter with a much lighter cargo. But if the winter Atlantic load line be fixed as the legal maximum on all voyages, it would be seriously, unjustly, and unnecessarily restricting the vessels' carrying power on the short summer voyage, to an extent which would perhaps destroy all hope of a profit on such voyages, with foreign ships in competition. On the other hand, if the maximum safe load line for a summer voyage across the English Channel be regarded as the legal maximum load line for any voyage, it would inevitably lead to this load line being adopted for other voyages, for which it would be positively dangerous. Between these two extremes there is for every ship an endless number of safe and proper load lines, each depending upon the particular voyage, the season of the year, and the nature of the cargo and storage. Hence the difficulty and almost impossibility of fixing by law any hard and fast load line, even supposing the difficulty of framing a rule which would apply with equal justice to all vessels to be definitely overcome. Mr. Plimsoll's original idea of fixing the load line by act of Parliament must therefore, be abandoned. There can be very little doubt that the Royal Commission, after all the evidence they have heard on the point, will go dead against it. And as Mr. Plimsoll himself has recently found a substitute for his previous load line, we may expect that we have heard pretty nearly the last of a "hard and fast" load line for a long time to come. Yet no one acquainted with the subject can doubt that overloading exists to a fearful extent in the mercantile marine, or that a very large proportion of losses is due to this cause alone. We do not here refer especially to the flagrant cases, which are for the most part being picked up, or indirectly prevented by the vigilance of the Board of Trade. What we refer to more particularly when we speak of the dangers of overloading, is the great temptation there is, even among respectable shipowners, to increase imperceptibly the amount of cargo, until the practice becomes countenanced, and in the end prevails, of loading vessels, and especially steamers, deeper than they should be loaded. Many vessels are constantly running in this condition, while everybody connected with them has got to believe that they are in perfect trim. They have perhaps met heavy weather on more than one occasion, and behaved well. This confirms the practice, but a time comes at last which finds out the weak point, the weather is called extraordinary, and the vessel goes to the bottom. This is not criminal overloading, but the result of ignorance on the one hand owing to the absence of any recognized standard of reference as to safe loading, and on the other the effect of keen competition and a desire to make money as fast or faster than others in the same line of business.

Among the various proposals for lessening these dangers the most simple and practicable are the following, namely:

1. To place on every vessel amidships

a scale of feet to mark the freeboard in somewhat the same way as it is now insisted upon for marking the draught of water forward and aft.

2. To place on the side of every vessel amidships a mark or marks showing the height at which a certain proportion of the internal capacity would be cut off and be above water if the vessels were loaded down to those marks.

3. To determine upon a scale of freeboard which would apply equally to the different types of vessels, and represent what would be a fair load line for the vessels upon ordinary voyages. To recognize this load line, not as a hard and fast load line, but simply as one for guidance, and to throw the onus upon the shipowner in the event of his loading beyond this line; of showing that the circumstances atttending his doing so, such as the nature of the cargo and the voyage, the season of the year, and the construction of his vessel, were such as justified him in taking in more cargo than would otherwise have been deemed safe loading.

The first proposal is the simplest of the three, and the reasons to be urged in favor of a compulsory lettering of the freeboard amidships are at least as strong as any that can be urged for making every vessel have the draught of water marked on the bow and stern. It would enable the officers of the Board of Trade, or any others interested in the loading of the vessel, to read off the amount of freeboard as easily as they can now take the draught of water, and the two sets of figures in themselves would enable a rough idea to be formed on the spot as to the extent of the loading. This simple action might form a check upon overloading, but it is only likely to do so indirectly by acting upon the fears of the owners as to some possible contingency. It would cause a certain restraint, but it would unfortunately act least powerfully on the more reckless, and would cause uneasiness and uncertainty in the minds of those only who are most anxious to do only what is safe and right. There are other objections to this proposal, which all apply to the proposal No. 2, and they will be considered under that head.

The second proposal, which is generally known as Mr. Rundell's, is to mark the percentages of spare buoyancy amidships, or more correctly speaking to mark the percentages of internal capacity which would be above water at certain draughts of water. If we were dealing with vessels all of the same type, or approximately so, this plan would doubtless meet with general approval, because then a mark showing say 25 or 30 per cent. of spare buoyancy would form a fair general guide for loading. It would have this merit over merely marking the freeboard by feet and inches, that it would place full and fine vessels upon an equal footing. There would of course be the difficulty between ships of different sizes, because universal experience is in favor of allowing a larger proportionate amount of freeboard or spare buoyancy in large vessels than in little ones, so that there would probably have to be a sliding scale of percentages somewhat similar to the present sliding scale of inches clear side per foot depth of hold known as the Liverpool rule for freeboard. And here we come immediately to the chief obstacle to Mr. Rundell's proposal. He has suggested the marking on all sailing ships the height at which one-fourth of the internal capacity or 25 per cent. would be cut off. This would be pretty near the load line for small ships, but would be far too deep for large ones, and would be a direct encouragement to large vessels to load down towards it. Would it not, therefore, when we are placing a percentage marked on the side of a vessel, be better to put one which would indicate the depth to which the vessel could fairly be supposed to load than to a mark likely to mislead.

When we come to steamers, with all their varieties of type, proportions, and superstructures, the objections to placing a uniform fixed percentage mark on all of them becomes far more serious than in sailing ships. In the first place, there, is a difficulty in many vessels of knowing to which deck the spare buoyancy should be estimated. There are, in addition to the complete three-decked steamers afloat, many having spar decks, or awning decks, and others which are really spar-decked vessels, but without the title. Some of these should, in all fairness, have the benefit of having their spare buoyancy estimated to the upper deck, while others should only be estimated to the main deck, and to discriminate between them, some standard as to

strength would have to be instituted, which would lead to endless difficulties, and open up the broad question of proportioning freeboard in relation to the structural strength. Mr. Martell, who has devoted much attention to this question, says, in his able paper "On Freeboard," read before the Institution of Naval Architects, and reprinted in *Engineering* May last, "Thus, in a flush-decked vessel having a surplus buoyancy of 27 per cent., by the erection of a raised quarter deck it would be reduced to 24½ per cent.; with the more perfect protection of a full poop, it would be reduced to 23½ per cent.; with the entire main deck covered in with an awning deck, it would be reduced to 19 per cent.; with a spar deck lightly constructed as described (having only half the frames extended to the spar deck), it would be less by 13½ per cent.; and in spar-decked vessels of various degrees of additional strength above the main deck, the surplus displacement to the same deck would be reduced in relation to the nearer approach of the topsides to that of a three-decked ship."

Here, then, we may have in two ships of the same principal dimensions a difference of 13½ per cent. of spare buoyancy between the suitable load line for each type, owing to one having a light covering deck, and the other being without any means of carrying up the protection for her engine and other openings above the main deck.

To put the same percentage mark on all these vessels, whether it happens to come near the point to which they should be loaded or not, can scarcely be considered otherwise than going to a great deal of trouble to teach people how to load their ships, and shirking the main point on which they wish to be enlightened, viz., what would be a fair draught to load their vessels to.

It may be said that marking the freeboard in feet and inches equally shirks the difficulty of affording any guidance for loading, and that is quite true. But it does not pretend to do more than record the freeboard, whereas it would be impossible to go through the scientific process of obtaining a percentage of spare buoyancy without making people believe it was giving them a mark for their guidance in loading. It would be just the same if we decided to mark a freeboard on all vessels of three inches to the foot depth of hold. We should be indirectly countenancing a false standard of loading, although it might not be intended that all vessels should load to that depth.

The third proposal to which we have referred is that laid by Mr. Martell before the Royal Commission, and since embodied by him in his paper "On Freeboard," from which we have already quoted. Mr. Martell admits the impracticability of fixing a hard and fast load line to all vessels, irrespective of the nature of the voyage and cargo, but he maintains that for every vessel there is a certain load line which is as deep as she should go to for ordinary voyages, and this load line he has embodied in a series of Tables, which form beyond question the most valuable documents yet published on the loading of merchant ships. These Tables afford a ready means of arriving at the freeboard of any vessel from her registered dimensions of length, breadth, and depth, and her register tonnage under deck. They are based upon the principle of allowing a certain proportion of surplus buoyancy, but with this principle modified, and very properly so as we think, by additions to the freeboard on account of extreme proportions of length to beam. Mr. Martell takes the ground that if we interfere with loading to such an extent as to mark the sides of all ships, we should place the mark at what would be a fair load line for ordinary ocean voyages. He contends against this being regarded as a hard and fast load line, and thinks the owner of the ship should be allowed to load beyond this line if he chose, but that in the event of a casualty he should be required to justify his having done so according to the circumstances of voyage and season.

It seems obvious that if the officers of the Board of Trade, or any other public officials, are to be held responsible for stopping overladen ships, they must have some rule to fall back upon, if it is simply for the purpose of conducing to uniformity of practice throughout the country. It is equally clear that if a hard and fast line is impossible, the next best thing is an average load line, suitable for ordinary voyages.

The elements necessary to be combined in a reference standard for loading are: first, simplicity of application; second, to be in accordance with the best experience

obtained with various types of vessels; and third, that it should be based upon sound principles, so as to secure general as well as individual accuracy, and avoid leading to the construction of ill-formed ships. These elements have been combined by Mr. Martell with very considerable success, and they will do much to secure at least a tacit recognition of the Tables. It can only be by continued application of the system that shipowners will learn its value, and this is a question of time. On the other hand, if it gains the confidence of the shipping community, it will soon become a standard of reference in the law courts and about the docks, and would have to be recognized by the Government officials and underwriters' officials who have to watch the depth to which vessels are loaded for their outward voyage.

To conclude, it would appear that the freeboard amid ships in feet and inches is almost a necessary preliminary step in any attempt to check overloading, but that it cannot be more than a mere step until it is accompanied by some standard of reference as to what is a fair load line, which, if we judge Mr. Martell's scale of freeboard rightly, has been well supplied by him. But it is probably better, on the whole, that his Tables should be allowed gradually to assert themselves, than that any official stamp should, at least yet, be placed upon them by the Board of Trade or by Lloyd's.

Of Mr. Rundell's proposal, we can only say that it would require active official interference and great labor to place his percentage marks on all ships with any degree of accuracy, which, in itself, is enough to prevent its adoption, and that when they were placed on vessels they would be more likely to prove misleading than to achieve the object sought by their author.

RIVER EMBANKMENTS.

From "The Engineer."

The permanent effect resulting from the embanking of the tidal or non-tidal portion of the river will in a great measure depend upon the precise object sought to be accomplished by the embankment. This object, or primary purpose, as it may be termed, is not the same in all cases, although to assume that it is, is not unreasonable. In one case the immediate point kept in view may be the preservation and protection of the banks and adjoining district, without any regard to the subsequent improvement or deterioration of the river itself. In another, the conditions may be reversed, and the improvement of the river considered as the chief feature in the undertaking, any benefit that may accrue to the riparian property being contingent. The third case, that in which the objects of the embankment are effected in their fullest and most legitimate manner, is when due regard is had to both the land and the river, and their mutual amelioration is the result of the project. Under the first category are included all embankments and walls erected solely for the reclamation of land, while the second embraces rather a peculiar class, affecting only the navigable channel of a river. These are known as training or low water walls, and are constructed for the purpose of causing a river to preserve a uniform permanent course. There are very few rivers which will in their natural state preserve the same channel for any length of time. This tendency to deviate from course to course, which is influenced more or less by the nature of the river bed, and the manner in which the stream is acted on by the wind and tide, causes a continual variation in the depth, and renders the maintenance of a navigable channel well nigh impossible. The effect of the training walls is to maintain the current constant, both in direction and strength, and of a uniform depth. Many of these walls, which have an average height of four feet above low-water level, have been constructed for the improvement of the Ribble and Tees. The recent opening of the Chelsea Embankment, extending on the Middlesex shore of the Thames from Battersea Bridge nearly to Chelsea suspension bridge, a distance of upwards of three-quarters of a mile, affords a favorable opportunity of adverting to the general scheme of the embanking of our metro-

politan river, and the possible effect that may result from the combined action of the embankments and the bridges. We may omit all consideration of the land which has been reclaimed, utilized and made a source of profit, both publicly and privately; neither shall we allude to the sanitary phase of the question, which is endowed with merit of an unquestionable character, so far as concerns the metropolitan portion, strictly speaking, of the river.

In the improvement of rivers, the removal of all obstacles and impediments to the flow of the tide or current is invariably regarded as the first step to be adopted. These impediments are of two kinds. They may consist either of objects placed in the open waterway of the stream, such as the piers of bridges for instance, or of others connected with the shore and projecting from it. Let us take the former, and consider what happens supposing the tide be running out. The water as it breasts the impediment to its flow, rises in front of it, and becomes piled up against it, thus creating an artificial head. The consequence is, that at and in the immediate vicinity of these obstructions the scour is increased, and a considerable quantity of material dredged or scooped out from the bed of the river. After passing the obstacle the head of water diminishes, the velocity of the stream is reduced, the solid matter held in suspension is deposited, and the periodical repetition of the same operation speedily leads to the formation of a shoal. The greater the breadth or face of the pier individually, or the greater the diminution of the waterway caused by all the piers collectively, the greater will be the obstruction to the flow of the stream, and the injurious consequences will be augmented in the same proportion. Arguing, therefore, on these grounds, we should naturally expect a shoal to be formed between any two bridges situated tolerably near each other over the same river. Experience has proved this to be the case with the Thames. A very formidable shoal existed between Westminster and Waterloo bridges, and to a great extent still exists. The removal of this was one of the improvements in connection with the river recommended many years ago by the first Commission who reported upon the project for embanking the Thames. An excellent idea of the practical piling up of the water against the piers of one of the Thames bridges may be gained from the deck of one of the river-steamers while passing under the arch of Vauxhall Bridge when the tide is running out strongly. The spectator will have a better idea of the great force of the current and the attendant scour if there happens to be a stiff head wind blowing, and the boat, as sometimes occurs, cannot shoot the bridge, but is compelled to put back and land him and the rest of the passengers at the Vauxhall pier down stream.

The same phenomena attend the existence of lateral obstructions, or those arising from the projection of objects into the waterway, from either one or both shores. Groins are of this description, and before the principles which govern the flow of rivers were well understood, were frequently adopted as measures calculated to improve them. But although sometimes locally beneficial, in the long run they are ruinous to the navigation of the stream. A very remarkable instance of the tendency of all obstructions to produce currents and distortion of the bed of a river occurred on the Tay.* A vessel of about 170 tons broke its tow line and grounded when there was some flood in the river. In the course of a few tides a regular pool was scoured out close to where the ship lay to a depth of ten feet. The gravel and other *débris* excavated by the force of the current, and amounting to about a thousand tons, was deposited in the form of a shoal or bank immediately below where the vessel lay, and rising to a height of five feet above low water. The formation of this shoal was evidently owing to the increased scour due to the artificial head of water raised by the obstruction, since the force of the current in its natural state was not sufficiently strong to act upon the bed of the river. The water-gate between Charing Cross and Waterloo bridges no doubt acts in the light of a lateral obstruction, and it is easy to trace at low water the formation of an incipient shoal, which will eventually assume more important proportions.

* "The Principles and Practice of Canal and River Engineering," by David Stevenson, F. R. S. E.

The general result of embanking any river is to contract the waterway, accelerate the velocity of the current, and consequently increase the scour. The tendency to scour out holes in some places and create shoals in another, is much enhanced when a tidal river, such as the Thames, for instance, is embanked for only a very small portion, comparatively speaking, of its entire length. Uniformity in the depth of water and in the velocity of the stream are the principal features which impart a navigable value to a river, and these it is impossible to retain, even if they once exist, in cases in which merely local improvements are effected. As an instance of the effect of embanking, dredging, and generally improving a river upon the bridges crossing it, we may quote from the authority already alluded to, the case of the Clyde. The Hutchison Bridge, which crossed the Clyde at the site of the new Albert Bridge, was erected in 1832. The masonry of the piers was laid at the level of seven feet below the bed of the Clyde, on a platform of timber supported by piles about eighteen feet in length. A section of the river at the site of the bridge was taken thirteen years after its erection, and it was found "that the level of the river had been lowered, in consequence of the improvements of the Clyde trustees, no less than eleven feet." The bridge was subsequently removed, and replaced by a new one. It is only fair to mention that even with the additional eleven feet scour the bridge might have remained safe, but the removal of a weir situated a short way above it rendered its removal indispensable. We are far from asserting that the case of the Thames is strictly analogous to that of the Clyde—although the velocity of the two rivers is about the same—but there can be no question that there is a tendency to a somewhat similar result with regard to the foundations of the bridges, especially those which have piers of masonry. It has been stated on good authority that shortly after the completion of that portion of the Embankment extending from Waterloo Bridge to that of Charing Cross, a large quantity of stone was pitched in round the pier of the former structure, which was nearest the Middlesex shore, with the object of forming an apron, and thus protecting the foundation from the action of the increased scour. If protection of this kind be really required now or at some future time for the foundations of any of the older bridges over the Thames, something more efficacious than loose stone must be employed to restore the original bed of the stream displaced by the scour. A steamboat was sunk in the Thames not long since by grounding on stones scoured out of their proper bed.

Without wishing to be alarmists, it is undoubtedly manifest to any one who has been in the regular habit of using steamboats for the last seven or eight years that a good deal more of the concrete in the Middlesex piers of Westminster Bridge is visible at low water than used to be the case. While we have every reason to be justly proud of our magnificent embankments, we ought not to shut our eyes to possible contingencies based upon the principle of hydraulic engineering. It is rare in mundane matters that good comes perfectly unalloyed with evil.

EASTERN ARTISANS.

From the "English Mechanic."

In offering some random observations on this subject I do not pretend to bring forward any new discovery in the way of mechanical construction from workmen who, from the long habit of using Nile mud only in their building operations, and of dabbing together various articles for domestic use of the same material, have consequently but a very crude notion of making anything either straight, square, or round. A few points, however, attracted my attention, that may bear curious comparison with the refined mode of working in other countries.

During a stay of several weeks in one place on the banks of the Nile, some half-dozen men brought down on the backs of donkeys a quantity of second-hand timber, of every variety of shape and dimension. One of the gang set to work on a large bag of old bent rusty nails of all sizes, and proceeded

to straighten them by laying them in a charcoal fire picking out the hottest as they came, with a pair of forceps, and flogging them out upon a block of granite. I soon saw that it was their intention to build a candjia or small trading boat, for sailing up the river, from the banks of which another man fetched a number of basket-loads of mud, and built up an arrangement for melting pitch, this was constructed of mud and bore a grotesque resemblance to a common laundry copper.

With a proper selection of crooked pieces of wood, and others made to suit by diligent adzeing, the framework of the vessel was quickly set up bottom uppermost, each rib as it was added being held in place by a temporary stretcher, aided beneath by props of mud. No mould-boards were used that I could perceive, nor reference made to any plan; the model was arranged apparently by sight. The ribs, when all in place, presented a very fair outline of the usual Nile form of hull, that is, with the heaviest draught forward. As to the formation of these ribs, they had to cut their coat according to their varied stock of cloth, and no one matched the other in size and quality of timber. For example, there would be a square section of rib on one side, and the opposite one consisted of a round piece of wood, if it happened to suit in outline, and perhaps a long rib in another pair would be matched by several short bits, to make up its fellow, but these irregularities were distributed judiciously with regard to strength. Next came the planking, and in this they displayed their best skill. The only cutting tool employed was the "quadoom," a kind of short-handled adze, which they used very dexterously, trimming the edges of the planks to a pretty close fit where they came together. The back of the adze served as a hammer, and as in all their kit they only had the fragment of a saw, most of the planks were cross-cut by notching on each side, breaking off the piece and trimming the end with this universal tool. In order to economize wood (which is very scarce and dear in the country) the planks were not cut to match, or to waste, but laid on in all sizes and lengths. As soon as there was sufficient planking to hold the ribs together, the vessel, by dint of much heaving and shouting, was rolled over so as to lie in all positions, for convenience of working. The seams were caulked just the same as here, and when this rudely-constructed vessel was finished and payed, it was surprising how well and shapely she looked. Like all of her class, with cargo on board, the gunwale would be only just above the water level, therefore the most crazy planks were reserved for the barrier of wash-boards made water-tight, and fortified outside by a stately embankment of Nile mud, which in that country dries again very soon after it is wetted. Treenails were not used in the construction, for of these they seemed to have no idea; in fact, they had no augers in the proper sense of term. If a hole of extra large size was required it was rimered out from a smaller one, with a cross-handled implement having a flat bit, shaped like the blade of an oyster-knife. The whole hull was fastened together by an enormous amount of nailing, and as this required a vast number of holes to be bored, these were made with an ease and celerity that would have put our best modern gimlets to shame, for much of the wood was acacia, and rather hard. The tools used were a kind of drill constructed as follows: a short stout piece of iron wire was driven into the end of a straight stick or staff, about one inch in diameter, and from twelve to eighteen inches long. An old ferrule or a few coils of wire prevented the ends from splitting. An inch of the other end of the staff was cut round as a shoulder, and the projecting piece whittled into a kind of knob, which was forced into a hole bored in a nut of the Doum palm. This knob must be rather larger than the entrance of the hole in the nut, and this having been scooped hollow when the staff is driven in, the nut, though quite loose, cannot fall off again. This served the same purpose as the handle of a joiner's center brace, and as the ivory-like substance of the nut is of an unctuous character, the rubbing parts do not chafe, but acquire a fine polish. This tool is used by grasping the nut as a handle, and rapidly rotating the staff by a drill-bow, consisting of the leaf stalk of the date palm, strung with a thong of hide. The various sizes of wire were quickly sharpened by merely hammering the end on a piece of iron and then rubbing them on a lump of grit-stone.

This leads to a description of the way in which the Turkish pipe-stems are bored. Curiosity prompted me to ascertain how this was done, for some of the stems are six feet long and drilled quite true and central throughout. The best sticks are said to come from the country near Constantinople, and are cut from a kind of dwarf cherry, spec-

ially cultivated for the purpose, and trained to grow perfectly straight; many are, however, obtained from oleander bushes in the valley of the Jordan. If the sticks are not quite straight when they reach the pipe-maker's hands he soaks them and dries them again under due pressure.

The workman squats before a log of wood driven into the ground or floor. In the top of the log there is an upright iron pin about an inch and a half long; a bobbin exactly resembling a common cotton-reel fits freely upon this pin. In the top of the bobbin is driven an iron-wire punch less in diameter than the intended bore of the pipe; the upper end of this wire is spread out by hammering, and made sharp like a brad-awl. A conical centre hole is dug out in the end of the stick to be drilled, this is set on the top of the sharp wire, which is rotated rapidly to and fro with a bow, the thong of which passes round the reel. For convenience, the work is usually begun with a short wire drill, and when all of this has entered, a longer piece with its attached reels, is substituted. The drill acting vertically, the fine borings fall directly out without clogging, or the necessity of withdrawing the drill till the work is completed. There is, however, one very important condition essential to the success of the operation. While the stick is being drilled, it must be held somewhat loosely in the hand so as to be continually shifting round; if this is not attended to, the bore is sure to run out of the centre of the stick. This may be exemplified by the operation of drilling up a brass wire for the purpose of forming a tube of small bore. If we attempt to accomplish this by fixing the wire in a vice, however carefully the drill is used, it will run out to one side before it has gone an inch deep. But if, on the other hand, the drill (formed of a piece of steel wire sufficiently long) is held as a fixture in the vice, and the wire to be drilled rotated on to it with a bow (the wire having a reel thrust on to it for that purpose) the bore will continue exactly in the centre of the wire. One end of this is pointed to run in the breast-plate and the other is marked with a centre punch, so as to run true on the drill point, this will come out at last precisely in the centre or point of the wire.

Disgressing from the question, in certain cases of moving the tool or the reverse in rotating work, it may be remarked, that in screwing wires, a far truer thread is obtained when the work is turned into the dies, and skilled gas-fitters well know that they get a thread free from drunkenness by fixing their die-stocks in the vice and screwing the gas-pipes into them.

Analogous to the pipe-stem boring, is the operation of the machine employed at the small-arms factory at Enfield, for drilling out the long hole in wooden gun-stocks for containing the ramrod. This is done with a long shell auger, but if this alone revolved the hole would never continue straight, but tend to follow the grain of the wood, as the slender bit is elastic and yielding. In order to prevent this, while the bit is rapidly revolving, the gun-stock also revolves more slowly in an opposite direction; this causes the hole to run true, however cross-grained the wood may be.

I once entered an armory in the East, where they were stocking and putting together common flint-lock horse-pistols, a brace of which every swaggering fellow likes to carry in his belt during an excursion. I, however, left in disgust, seeing that there was nothing to learn. They had no work-benches, but were all seated cross-legged on the ground, some using their naked feet to hold the work, a very common practice throughout the country, for when a man has gone all his life-time without shoes and stockings, his toes get properly exercised and developed, and become rather prehensile. At Cairo I once stopped to look into the stall of a man who had mounted a grind-stone, and gained his living by grinding edge-tools. There was no treadle fitted, he sat at the stone bicycle fashion, and turned the handle directly with his foot, hooking his great toe on to the iron crank-pin, round the end of which it had worn out a soft luxurious hollow, having an exquisite polish.

A number of fire-arms of the rudest construction are yet made in the East by the Arabs, but they all appeared to me to be very insufficient and harmless, and the old match-lock is still carried by some of the wandering tribes. During our travel through a part of Samaria, it was considered prudent to hire a Government escort, as the authorities then, to some extent, became responsible for any outrage on travellers. Accordingly we were provided with two "soldiers," mounted on pretty fleet horses, but the men had nothing, in dress or appearance, to denote a military calling or anything in their favor to distinguish.

them from the thieves against which they were sent to protect us. One of them was armed with a long spear only, the other had dangling at his side a most ridiculous abortion in the shape of a blunderbuss of native manufacture only eighteen inches in length. This suspended by a single sling from his neck, danced frantically about as he rode. The stock was too short to be held to the shoulder, and it would have to be fired pistol-fashion. The muzzle of the barrel was as large as an egg-cup, and the bore dwindled down to the size of a candle-socket at the breech. Irrespective of the moral effect its appearance might produce, I concluded that practically this must have been more a weapon of castigation than destruction, for if loaded with a charge of slugs, and fired into a group of men at a few yards distance, from its scattering proclivity, it would probably hit them all, and might perhaps break the skin and draw blood in a bare place without the risk of penetrating.

An Arab once undertook to guide us to a place where sport was to be had in shooting hares. He himself was armed with a native flint musket, tremendously long in the barrel; this was fastened to the wood-work of the stock by some dozen brass bands or ferrules, which he prided himself in keeping particularly bright. He soon shot a sitting hare, creeping up as close as possible. He asked us to reload his piece; this we were about to do with three drachms of English sporting powder. He said this would not do, as his gun would not kill unless it had six or eight drachms; this we gave him on his own responsibility, thinking it not unlikely that with our powder his frail piece would be blown to bits, as the substance of the barrel was scarcely larger at the breech than at the muzzle. When he fired again he neither hurt himself nor the game. An examination of the weapon explained the mystery, for the touch-hole was quite one quarter of an inch in diameter, thus acting as a kind of safety-valve, giving vent to more than half the force of the powder while the surplus was driving the charge. Barbarous as these weapons are, both in design and workmanship, yet the barrels of some of them are fine specimens of forging. I particularly remarked one piece; t was short carbine with silver bands to hold the barrel to the stock, which was also ornamented with silver. The barrel had not been bored, and was of a very curious pattern, not a spiral twist like ours, but an assemblage of fine bright fibres crossing in every direction. I was told that this was made at Damascus, and during my stay at that city I entered a smithy where arm were made.

The only fuel used was a fine quality of hard-wood charcoal. The bed of the forge was raised the same as here, but the curious feature was the back, which consisted of a slab of a light porous kind of fire-stone. Under this the blast entered, the tuyere appeared to me not to be a round aperture as with us, but was extended horizontally about two inches. Opposing the back there was a similar slab of fire-stone, which was set at various distances, according to the magnitude of the work to be heated. If this was small there was not more than an inch between the slabs for containing the ignited charcoal. The faces of the stone acquired a white heat, which was thus confined and reverberated on to the work, with but a small consumption of fuel. There were two single bellows of a circular form, connected by a rocking staff, so that while one of them was brought down the other was being raised and filled, thus giving a continuous blast. It might be supposed from this description, that the arrangement was rather a primitive and ineffective one, but the work done proved quite the contrary. The superiority of all ironwork forged with charcoal is well known, but if this were used in our form of forge with weighted bellows, it would be rapidly blown away. In the Damascus forge the pressure is obtained by the direct muscular force of the arm, so that the smith can regulate his blast by feeling, and instantly increase or diminish its force, or stop altogether, according to the state of the work; and the charcoal being confined in a narrow space between two walls of non-conducting fire-stone, the escape of heat as well as fuel is prevented.

New Nickel Mine.—Two rich veins of nickel ore have recently been discovered in the northern part of New Caledonia, the penal colony of France. Concessions have already been asked from the government for its exploration, which, however, cannot be well commenced before roads are opened to transport the products of the mine to an available harbor, at the sea-shore. As there are already mines of other metals on that large island in operation, there is a high expectation for material progress there.

ON VAULTING.*

By T. H. EAGLES.

From "The Building News."

The influence (all important and all pervading) which the persistent and unwearied attempts of twelfth century builders to erect over their buildings a substantial and permanent covering of stone, had on the architecture of subsequent times is now well known to all who have given any attention to the subject. It will probably be now admitted by every one that it was the working out of this problem which gave birth to almost all the distinctive characteristics of Gothic architecture, and the fanciful yet ingeniously supported theory that the "clustered and banded stalks of the lofty pillars, the curling leaves of the capitals and cornices, the interlacing arches of the fretted vaults" of the cathedrals of the Middle Ages, are attempts to reproduce in stone "the awful gloom of the deep forests of the North, the aspiring height of the slender pine, the spreading arms of the giant oak," must now be given up by all except the poetic "Quarterly Reviewer" who has the confidence to maintain that these glorious unities, these perfect wholes, were the result of a number of uneducated workmen each doing that which was right in his own eyes without consultation or superintendence. It was, I believe, Ware, in his "Tracts on Vaults" who first showed vaulting thus to be the final cause of Gothic architecture, but since his time the question has been more thoroughly worked out, notably by Viollet-le-Duc, who in his magnificent "Dictionnaire," in the article "Construction," says:—"The vault being from this time forward" (end of twelfth century) "the generator of all parts of a vaulted building, fixing the position, form, and arrangement of the supporting masses, is the first thing we ought scrupulously to study. By one who thoroughly understands the structure of the Gothic vault and knows the infinite resources its construction presents to view, all the other parts of the masonry can thence be naturally deduced." Dr. Whewell, too, the late Master of Trinity College, Cambridge, in his "Architectural Notes on German Churches," considers "that the adoption of the pointed arch in vaulted roofs arose from the requirements of vaulting, and from the necessity of having arches of equal heights with different widths," and further that "from its original situation in the vaulting, this form of arch was gradually diffused into other parts of the building." This view is indeed disputed by Professor Willis (whose admirable paper on the Vaults of the Middle Ages renders the volume of the Institute "Proceedings" in which it appears one of the most valuable of the entire series), for in the preface to his "Remarks on Architecture," he observes "There is a fascinating simplicity about that theory" (of the origin of the pointed arch) "which would derive it from the requirements of vaulting, that makes one wish to find it true; but I am sorry to say that notwithstanding the favorable prepossessions with which I set out, I have been compelled to dissent from this ingenious hypothesis. I have shown that so far from the pointed arch being necessary to enable a parallelogram to be vaulted, it appears that architecture was already in possession of several methods of performing this, which were not even superseded by the introduction of that form, but continued in use to the latest period of the Middle Ages." These methods are of course those which prevailed among the Romans, and which are now known as Roman vaulting, but the vaults constructed on these principles are kept up and maintained in equilibrium solely by the inert mass of the supporting piers, the area of which is very large; and which, thanks to the splendid quality of the mortar used, so good as to have become proverbial, are practically homogeneous throughout, the cohesion being perfect. This was indeed the principle of Roman buildings. The Romans secured stability by the sheer weight of the resisting portions of their buildings; if, for instance, they feared that an arch would rise at the haunches unless an enormous load was placed there, instead of seeking a more scientific form of arch they simply piled on the required load, and so for the rest. Now it was not only possible but easy for

* Royal Institute of British Architects' Prize Essay, 1874. Read before the Institute on Monday evening, June 1.

the Romans, a powerful people, possessed of abundant means and appliances, with armies of laborers, with any quantity of materials, and above all, with a great love of show and disp'ay, both of their wealth and power, to build in this manner. Economy to them was no object, but when we come to the twelfth century, to people just emerging from the barbarism and ignorance and consequent poverty of the centuries following the downfall of the Roman power, the case was altogether different. At first, indeed, they seem to have attempted to imitate the structures which the barbarian incursions had spared (for I should notice that it is to the Continent we must go for the earliest Mediæval examples), but they speedily found the impossibility of continuing this method. With them the most rigid economy had to be practised, the utmost possible effect had to be produced with the materials used; nothing could be laid to waste, and therefore instead of relying on mass and mere weight, the thinking faculty had to be exercised, and so attempts which were gradually, though doubtless only after repeated trials and occasional failures, crowned with success, were made to balance opposing forces, to diminish thrusts and pressures, and to make the direction of these as vertical as possible, thereby simultaneously enabling the area of the piers to be safely reduced. These circumstances, I think, acting on the ever-present desire in the twelfth century for stone vaults, led directly to the results produced, and furnish a reason why the previously existing Roman solution of the problem could not be accepted, and an answer to Professor Willis's objection to the theory in question. The question why stone vaults were so much sought after in spite of all the difficulties attending their construction, and why the builders of the day were not satisfied with wooden roofs, is a difficult one to answer. Probably the danger which there always was in these unsettled and turbulent times of the malicious or accidental destruction of any important building by fire, had something to do with the matter. Certain it is that such an event was by no means uncommon, and the use of the more durable and permanent material was thus perhaps in a manner forced upon the designers; for there can be no doubt whatever that a brick or stone shell over the building, whether the same be the actual roof or not, renders it to a very great extent fireproof. Even where (as is almost universally the case) the vault is only a sort of inside ceiling, and is protected from the weather by a timber framed roof above, a careless plumber can do very much less damage than where in place of the vault there is only a wooden or plaster ceiling, for by cutting off air from below, the fire is checked and more easily mastered, as was strikingly exemplified at Canterbury at the time of the fire there in November, 1872, for though nearly two hours elapsed between the breaking out of the fire and any water being brought to bear on it, still it was confined to the eastern limb of the cathedral (where it commenced), and since the burnt and charred timbers fell in on the upper surface of the vault, and so were prevented from dropping into the choir below, scarcely any damage was done to the interior of the building. It is not too much to say, then, that the existence to day of this precious national monument is mainly due to its "stone ceiling," a very good reason for recommending similar construction where a durable building is required. On the other hand, York Minster, which is covered with a wooden ceiling of sham groining has twice within the present century suffered most severely from the ravages of fire. In 1829, the roof, the whole of the richly carved tabernacle work of the stalls, and, in fact, all the woodwork of the choir, were utterly destroyed, and it would be easy to multiply instances. Every one knows, however, that in England it was by no means the universal custom to ceil a building with stone; but if we compare the circumstances of our own country and those of our Continental neighbors, I think we may find reason for the greater prevalence of vaults there than at home, and which is of course another cause why the difficulties of vault construction were so steadily struggled against, and the system so pertinaciously adhered to. Our noble open timbered roofs are legacies of which we may well be proud, which have no rivals abroad, and which we owe in no small degree to the magnificent forest of oak trees for which England was formerly famous. The Romans seem to have drawn heavily on the forests of Gaul after those of Italy were exhausted, for timber for their immense naval and engineering works, and hence even as early as the middle of the twelfth century the provinces where the first glimmerings of returning

civilization had appeared, and where consequently the architectural art was most advanced, appeared to have been almost entirely cleared, and as a natural consequence, wood became a comparatively scarce and proportionately valuable material. Whether this be the explanation or no, we have abundant evidence to show that vaulting had advanced a very considerable way towards perfection on the Continent at a time when it was very little if at all practised in England; that it was then imported as it were complete as it stood; and that it throve so well after being transplanted as soon to surpass its parent stock both in beauty of design and careful execution; no Continental examples, indeed, can compare with the richness and skill displayed in some of our late ones, though it may be doubted after all whether these last may not be adduced as instances of the "vaulting ambition which o'erleaps itself." I do not propose to enter into any discussion as to the antiquity or invention of the arch. Many of the so-called examples of its early use would be very much to the point if it were not for the unfortunate circumstance that they in no way exhibit its principle, but consist only of a series of corbelled out courses with horizontal beds—a method impossible of application to the covering in of extended areas. It is enough to go back to the days when Rome became a mighty nation and was enabled to indulge in those tastes to which I have already referred. The occasion of the rebuilding of the city after the burning by Nero seems to have been taken advantage of for covering in many buildings with vaults, which until then had only wooden roofs; and none of the great vaults with which we are acquainted seem to be of earlier date than this. * * * * *

There are one or two examples of Roman vaulting, consisting of a series of parallel transverse arches within a short distance of each other, on the backs of which thin slabs of stone are laid, connecting them together in pairs and completing the covering. This system obviously favored economy in the centreing required, as continuous planking might be dispensed with altogether; but it was quite exceptional, the transverse arches being generally hidden in the thickness of vault. There is obviously in many points a striking analogy between it and the rib and panel vaults of a subsequent period. The foregoing remarks refer strictly only to what is known as a continuous barrel vault. This is what the majority of Roman vaults were; semi-circular, of course, in section; in fact, in appearance exactly like the upper half of most of our railway tunnels. Interpenetrations seem to have been avoided, at all events until the later days of the Empire, and if, from the necessities of planning, an art in which the Romans seem to have been great adepts, a vault had to abut end on to the direction of another, they frequently got over the difficulty by making one (the smaller of the two) at a lower level than the other, so that the springing of the larger one would be above the crown of the other—the minor vault would finish as a semi-arch in the vertical abutment wall of the superior. We know, however, from existing remains, that the Romans did not entirely shirk interpenetrations of curved surfaces, and this really brings us to the difficulty of the subject—groined vaults. If we have to cover in an exact square, there is obviously no reason why we should choose one pair of sides for direction of axis of our barrel vault, rather than the other; at least, if we are not hampered by any considerations of convenience in securing the necessary abutment; in fact, we might suppose a complete barrel vault to be turned across in each direction, and supposing that the two could co exist, the space below would obviously have a double covering. Now if we imagine the part of each vault which is above the upper surface of the other cut away, we should have remaining a sort of square dome, which would form a single covering over the entire space; while if we cut away the part of each vault which is covered by any part of the other, *i. e.*, which is below its under surface, we should have a roof with salient edges or groin over the diagonals of the compartment, and which no longer abuts continuously along its sides, but the entire thrust of which is transferred to the four angles, and which might be carried on piers there placed. Both these methods were used. The first is known by French architects as a vault "en arc de cloitre," the second is the ordinary "groined Roman vault."

Thus far all is plain sailing; the compartment to be vaulted being square, the diameters of the arches on each pair of sides (the generators of the respective vaulting surfaces) are equal to each other; the crowns in the centre of the compartment and the groins are plain curves. Each being only an oblique section of a right circular cylinder, its outline would

be a semi-ellipse, and by constructing wooden centres to this outline, arches could be thrown across from angle to angle of the space to be vaulted, and the entire vault could be completed exactly as before described, the only requisite to be observed being that the centre should be so much larger than the actual finished groin as the breadth of the tiles used required, in order that their angles should not project beyond the finished vaulting surface. As soon, however, as we attempt to cover in a parallelogram with the groin vault difficulties beset us, which are the greater the more the parallelogram departs from a square. The sides being equal, if we use barrel vaults, semi-circular in section, for the generating surfaces of our groined roof, we cannot at the same time have the springing line and crown of the smaller level respectively with the springing line and crown of the larger; but if we make both spring at the same level, the crown of the one is below the crown of the other, while if we make their crowns level, the springing line of the smaller is more or less above that of the larger. In both of these cases the groins are no longer plane curves. Notwithstanding these difficulties, vaults were constructed with these groins of double curvature, notably over the great hall in the Baths of Diocletian, now the Church of Sta. Maria degli Angeli, but the compartments do not differ greatly from a square on plan, the sides being as 4 to 5, the span 67 feet; yet even here the effect of the twist in the groin is, by universal testimony, exceedingly disagreeable to the eye, and causes a painful sense of insecurity. In the great hall of the Baths of Caracalla, the mere springing of the vaults remains, yet there are clear indications of the twist; the proportions of the sides of the compartments here are as 9 to 11, or a trifle more nearly square than the preceding. In consequence of these difficulties and objections, Professor Willis, in his "Remarks on the Architecture of the Middle Ages," observes: "It is no wonder that a new expedient was soon found to supersede it" (the twisting groin) "which appears to be the domical or inclined form of the vaulting cells." (The vaulting surfaces filled in between the supporting arches, or a skeleton framework.) "The whole difficulty of vaulting a parallelogram with quadripartite vaulting resides in the assumed necessity of preserving the apex of the vaulting cells horizontal, and making their surfaces cylindrical throughout. If we free ourselves from these conditions, it is easy to show that we can not only vault any parallelogram or trapezium, but that we make both arches and groin of any figure we choose. * * The ridge line of each cell, which may be curved or straight, will of course be more or less inclined according as the apex of the lateral arches is more or less below or above the intersection of the groin-ribs. In fact, this reasoning is entirely independent of the form of the arches, and bound only with the one condition that the diagonal groins must intersect in some point, and therefore gives a complete solution of the problem with semicircular arches only. Pointed arches might naturally be used instead of semicircular ones, after their discovery or introduction, and their convenience and strength would occasion them rapidly to supersede the latter. But that there was no necessity for their employment is clear, because this expedient of forming domical cells was known to the Romanesque builders, and used by them at Spires and other examples of the same age, before the pointed arch made its appearance. Nay, I am by no means certain that it was not employed earlier, for I have already shown that domical cells are to be found at Baiæ, in the Temple of Venus, and elsewhere, although I am unable to cite an example of them in a genuine Roman cross-vault." The roof of the above-mentioned Temple of Venus, however, it should be noticed, is a genuine dome on a cylindrical supporting wall, and not a vault over a rectangle. Summed up in the above short description, we find noticed the introduction of a principle of the greatest, in fact of quite cardinal importance in the construction of vaults. It is the vital point of difference between Roman vaults and those of the Middle Ages; introduced by Romanesque architects in a tentative sort of way, it was developed by them to a considerable extent, but could not get full scope while restricted to the use of semi-circular arches, and, I believe, the pointed arch followed naturally from the attempts that were made for its perfect development. It will be noticed that in the genuine Roman vaults the vaulting surfaces are of the first consideration, and the groins are merely the result of simple interpenetration of two or more cylindrical surfaces; this followed

naturally from the minds of these architects being preoccupied with the simplest possible form, the semi-cylindrical continuous barrel vault, and the changes to which Willis refers was certainly not so simple a one to make as he seems to imagine, and was never adopted by Roman as distinguished from Romanesque architects at all. Between the building of the baths of Diocletian and of the cathedral of Spires was an interval of nearly 700 years. The new principle introduced was of course that of making the groins regular curves, in no way dependent on the curve adopted for the vaulting surfaces over the sides of the compartment, and adapting the surfaces of the immediate vaulting cells to the outlines thus given to the "skeleton" framing of the vault. In the Roman method the vaulting surface was everything; it was made perfectly regular; the groins were subsidiary, and, as it were, an incident of the construction; in the new method the groins were of equal consideration with the bounding curves over the sides of the parallelogram, and the intermediate filling in became of but secondary importance. The true key to the solution of the problem of vaulting construction had now been found, a new path had been opened by travelling along which most of the difficulties which had beset previous efforts were avoided, and an impetus was given to the art which produced the happiest result. Working on this method, nothing, in the words of one of our greatest living architects, "is simpler than a good vault. The best rule for it is to make a good diagonal arch and a good transverse arch, and the filling in of the cells is pretty sure to take care of itself." The pointed arch was still, as I have said, necessary for the perfe tion of the new method, and for this reason: In a rectangle, the sides of which are, say as 2 to 1, the semi-circular arch on the diagonal (*i.e.*, the groin arch) will be more than twice the span of the semi-circular arch on the short side (the wall arch), and hence if we make these arches spring at the same level we must have a piece of dead wall (in height more than half-span of side arch) in order to raise the side walls of our compartment to the level of crown of diagonal arch. In order to allow the tie-beams of the sheltering roof to clear the vaulting, the side walls obviously had to be raised to this level, and hence the adoption of this method required an expenditure of labor and materials producing no adequate effect, which could not but be distasteful to builders possessing only such limited resources as did the early Romanesque builders of France and Germany. If, on the other hand, the crowns of the side arches were raised to the level of those of diagonal ones (*i.e.*, if the side arches were stilted more than half their span) it would follow that a horizontal plane through springings of side arches would cut the diagonal arches, and the vaulting surfaces would have to be skewed and twisted in a very peculiar manner.* The same objection would apply if we made the diagonal rib segmental, *i.e.*, if we made its rise equal to half-span of side arch, and in addition there would arise an awkwardness and unsatisfactory effect of the arch starting out of its pier at a decided angle, instead of growing gradually out of it in the manner so distinctive of perfect Gothic. All these methods and combinations of them were, however, adopted in the earlier days of the Romanesque period, the latter half of the eleventh, and the whole of the twelfth century; but an expedient which perhaps obtained more favor than any other was the following: The difference in the rise of the diagonal and side arches is less when the compartment is square on plan than when it is any other rectangle; the naves of early Christian churches were generally made almost exactly twice the width of the side aisles, and the span of the arches of the nave arcades was equal to width of aisles, hence the aisles were made up of series of squares on plan, and the vaulting there was comparatively simple; then, in order to get square vaulting bays in the nave, two compartments of the nave arcade were taken in to form each bay, and the diagonal arches were consequently supported by alternate piers, the distinction between those which carry both nave and arcade and superior vaulting, and the intermediate ones carrying arcade only, being variously marked. "This mode of vaulting with semi-circular arches both ways and with no diagonal ribs, is still found in several ancient churches, though it has often been replaced by more modern vaults. It is found with considerable dimensions in the churches of S. Maurice

* In vaulting of all periods we frequently, indeed generally, find the wall rib stilted, and the consequent twisting of the vaulting surface, but the height of the stilt is much lessened by the use of pointed arches; by its use excessively acute arches are avoided.

and S. George, at Cologne; the ancient monastery churches of Laach, near Andernach, and Eberbach, near Elfield; and on still a grander scale in the gigantic cathedral of Spires, where the span of the vault is about 45 feet; and though the storms of war have so often and so fiercely burst upon this city, it is confidently asserted by the most learned antiquaries that part of the vaulting is of its original form. In most of these instances, and especially at Spires, the compartments are considerably domical, the intersection of the diagonals being higher than the summits of the bounding arches."* The method, however, can only be deemed an expedient, and an evasion, not a solution, of the problem of how to vault over a parallelogram. The pointed arch alone enables this to be completely and satisfactorily accomplished, as with it we can make an arch of any span and any height. Suppose we have to construct a groined vault over a rectangle 40 feet by 20 feet, the length of the diagonal will be 44 feet 8 inches nearly, and a semi-arch described on it will rise about 22 feet 4 inches. If we decide to make our ridges level, the arches over the sides may be made of the following forms: The transverse arch may be struck with the same radius as the diagonal, and the radius of the wall arch (over the short side of the rectangle) will be 30 feet. There is here no waste of space, the filling in of the spandrels is simplified, and the construction is comparatively easy. We have now reached a stage when a fresh feature is introduced. In genuine Roman vaulting the ribs were almost, without exception, hidden in the thickness of the vault; the filling in was packed in between them, and the intrados, or under surface, was flush from one end of the building to the other; it became a homogeneous crust without elasticity, and which ruptured if by chance there was any settlement of the walls; but the very earliest Romanesque builders seemed to have aimed at securing a certain amount of elasticity in their structures (which indeed economy imperatively demanded), and their vaults were formed of shallow courses of unhewn stone, bedded in mortar, but arranged as quasi voussoirs. To stiffen these shells, transverse arches were turned across from pier to pier; but instead of being hidden in the thickness of the vault, they were built underneath it, appearing as projections from the general surface, and forming a permanent centreing. These are referred to by Whewell in the quotation just given, and on reference it will be seen that he also points out that similar arches run from pier to pier along the clerestory wall. This was a further carrying out of the elastic principle: obviously by it the whole weight of the vault was carried directly by the piers, the clerestory walls being relieved of all pressure from it, and these arches could follow any small motion of the piers, accommodate themselves to their settlement or spreading, and still the concavity of the masonry shell above them be secure. To carry the principle to perfection, the groin or diagonal arch obviously required to be made to project like the transverse and wall arches, and then we get the full complement of projecting ribs, and the great æsthetic principle of the constructional parts being made visible and prominent was fulfilled—we have now perfect *quadripartite* vaulting, so called because it will be seen there are four vaulting compartments or cells in each bay, the development of each of which is a sort of triangle. The introduction of visible ribs was the cause of a somewhat singular modification of the method already noticed, in which two bays of the nave arcade were taken to form each bay of the main vault. It was felt, I think, desirable to remove, if possible, the inequality which necessarily existed between the alternate piers of the nave arcade. To effect this, transverse ribs were thrown across between every pair, but the diagonal ribs were turned precisely as before, and each pair consequently not only intersected each other, but also the crown of the alternate transverse rib. This transverse rib could not be left a mere stone arch supporting nothing, and at first probably a vertical wall was built on it up to the crown of the vaulting cell, resting on the diagonal and wall ribs. An instance of this still exists in the Abbaye aux Dames at Caen; but a subsequent improvement was to make the wall ribs one instead of two bays of the nave arcade in span, thereby forming in each complete vaulting bay six compartments or cells, the ridges of which would radiate from the centre of the bay to the crowns of the four wall and two main transverse ribs respectively; the four cells abutting on the clerestory walls being, of course, unsymmetrical about the ver-

* Whewell's "Notes on German Churches."

tical planes containing their ridges. There are numerous examples of this method—notably the Abbaye aux Hommes at Caen, contemporary with the Abbaye aux Dames; and in our own country the Choir of Canterbury. It may not be without interest to notice that in Sir G. G. Scott's competition drawings for Edinburgh Cathedral the choir is shown vaulted in this manner, which, from the number of cells in each bay, is known as *sexpartite*. With the introduction of the pointed arch and the thorough admission of the principle above mentioned, the making the ribs a sort of permanent centreing on which the filling-in could be laid, the principal difficulties of vault-construction may be said to disappear. Much, of course, remained to be done, but chiefly only affecting matters of detail, which the practical experience gained by every building raised tended largely to explain and show how improvement might be made. Such a point was the starting the ribs from the supporting pier. At first a single vaulting-shaft ran up the face of the clerestory wall—generally from the nave floor level, being attached to the nave pier, though sometimes starting from its capital or from a corbel in the spandrel between the nave arches, and on the abacus of this single shaft had to be found room for the springing of the transverse ribs, the two diagonal ribs, and the two wall ribs, though these last would appear to have been frequently omitted. At first no attempt was made to make the various ribs mitre or penetrate into each other, but each started independently from the supporting abacus.

* * * The necessity for providing a large area for the sitting of the springers of the various ribs frequently led to separate shafts being provided for the support of each rib, which thus each had a separate capital from which to spring. We have here obviously the first germ of the clustered six. A very early example is given us in the nave aisles of Peterborough Cathedral. The nave is covered with a wooden roof, and was probably never intended to be vaulted, since shafts for the diagonal ribs are only provided next the aisle, while the half-shaft towards the nave, instead of stopping at the string under clerestory windows, which would be the springing line of the vault, is continued right up to the string over the clerestory window arches, and there finished abruptly. The tie-beams of the original roof probably rested on them, though these have, of course, disappeared. I was unable to get the exact curvature of the ribs of these aisle-vaults. the transverse ribs are semi-circular and considerably stilted, while the diagonal ribs are segmental, with their centres some distance below the springing line. The effect of this is to throw the diagonal ribs forward; so that looking down the aisle, part of each transverse arch is cut off, as it were, by the diagonal rib in front of it; and in order to avoid excessive twisting of the vaulting surface, each diagonal rib has to have a backing piled on its extrados, upon which, as on a centre, the actual filling in is laid, exactly as noticed by Professor Willis in the castle at Newcastle-upon-Tyne, and in the ruins of Finchall Priory, Durham. The transverse rib consists of two rolls, with a V-shaped member between them, while the diagonal ribs are exactly like those of the preceding example. The next great improvement consisted in making the ribs run into or penetrate each other. This of course greatly reduced the area of the vaulting springer, and consequently also that of the supporting pier. As the principle, too, of Gothic vaulting was worked out, and the logical consequences of that principle freely and fearlessly followed and admitted, we find a change in the general outline of the ribs. Hitherto their breadth has been greater than their depth (the dimensions below the vaulting surface); but since the stability of the vault depended on these ribs, which were, in fact, a series of independent arches, a reversal of these proportions was the necessary and logical result of a due consideration of the property of the arch "that its stability increases with its depth." This, too, assisted in the concentration of the ribs, so to speak, on the supporting abacus. Careful management is required to make the various ribs mitre into each other properly. With ribs of various curvature, we are liable to find some particular one disengaging itself from the spandrel solid before its neighbors, which introduces a certain amount of awkwardness. This is noticeable in the vault over the chancel of S. Mary Minster, Thanet. It consists of four bays of quadripartite groining of varying widths, the first of which from the west is wider than the others. The transverse ribs are very obtusely pointed, almost semi-circular; the ridge from east to west is level. Their outline is segmental, not pointed, and consequently the

centre from which each is struck is at a greater or less distance below the springing line according to the greater or less width of the various bays. The various ribs in the spandrel solids all mitre very fairly; but owing to the greater span of the ribs, and their consequent greater obliquity to the vertical at their springing, they are thrown forward, and become detached from the rest before these last are completely developed, and the awkwardness spoken of ensues. The principle of making the ribs interpenetrate introduced a very important detail of construction. This consisted in forming the blocks of masonry at the springing (to a height such that the ribs by their spreading had completely disentangled from each other themselves, and could each be continued as a separate arch formed of independent voussoirs), with horizontal courses. This block is known by its French name of the *tas de charge*, there being, I believe, no equivalent term in the vernacular. The first two or three courses of the spandrel solid would each be worked out of a single stone only, and the pressure exerted by the various ribs being thus brought together in a single mass of material of comparatively limited area, would necessarily combine and produce a single resultant, the action of which could be resisted by judicious buttressing. The genuine arch construction of each rib would therefore begin only when it became entirely disentangled, as it were, from the other ribs, up to such a point, the construction being in fact mere corbelling out. * * The irregular mitreing of the moulded ribs which was unavoidable when the various ribs were all of different curvatures, must, however, have been felt to be somewhat unsatisfactory and defective, and when vaults of great span and formed of wide bays were attempted, in which, for the additional security of the filling in intermediate ribs between the transverse and diagonal, and diagonal and wall ribs were introduced, matters became still more complicated. The solution of the difficulty was found in making each rib a compound instead of a simple curve. By this means each rib, no matter what its span, could be formed with its lower portion of any desired curvature, and thus the simultaneous development of adjacent sides of the various ribs from the spandrel solid could be ensured. * * In vaults where the ribs are numerous and all parts of the same curve (fan vaults), the spandrel solid becomes practically a solid of revolution generated by the motion of a simple or compound curve round a vertical axis. Our own country is their home par excellence; on the Continent architects scarcely went beyond the perfect quadripartite vault, and though our late and elaborate examples are triumphs of stone-cutting and technical skill, they exhibit scarcely any new principle, and with the perfecting of the earlier method the difficulties of vaulting may be said to have been overcome. Such vaults, indeed, as those of King's College Chapel, Cambridge, and Henry the Seventh's Chapel, Westminster, must be considered to some extent debased, and as exhibiting false construction, inasmuch as in them the ribs are not veritable independent arches forming a permanent centreing, on which a thin shell forming the filling-in is laid, but the vault is really of solid masonry, the apparent rib of panel work being mere ornamental sinkings in the solid stones of which it is composed. Gorgeous though they are, still I think they are really of minor importance, and the interest of the subject is to my mind to a great extent exhausted when the problem which the early Romanesque builders set themselves to work out was once fairly and fully solved. I will conclude these hasty notes with the following passage from Street's charming book, "Brick and Marble in the Middle Ages;" it is, I think, worthy to be constantly in the remembrance of every architect: "The real beauty of these interiors" (of the churches in Venice) "is owing, I believe, more to the noble simplicity and purity of the quadripartite groining which arches them in, and which, even where other features would seem to tell of debasement and absence of feeling, invariably recalls us to a proper recollection of the infinite value of simplicity in this important feature. * * * It is not difficult to prove that this must be the case, for I take it for granted that we all feel that ornament for its own sake is valueless, and equally that doing in a troublesome and therefore costly way that which may as well be done in a simpler manner, is unpleasant and distasteful as an exhibition of the wasteful expenditure of human skill and energy; and therefore, as simple quadripartite groining with diagonal and transverse ribs, and none intermediate, is quite sufficient for construction, and is in no degree whatever strengthened by the multiplication and ramification

of ribs, common even in our early work, and in later days sinking into the effete and senseless luxury of fan tracery and its contemporary modes of vaulting—that, therefore, the simplest is the only true and thoroughly defensible system of roofing in stone.

NEW AND ECONOMIC PUMPS.

From the "Mining Journal."

The extreme simplicity and great water-raising capacity of the very primitive form of pump met with in some of the old Spanish mines, and consisting merely of a wooden tube, of length corresponding to the depth of the shaft, with an endless rope carrying at intervals a bunch of sheepskin, has been admired and favorably reported upon, so far as the principle is concerned, by some of the most competent engineers who have been intrusted with the management of mines in modern times, but all have concurred that obvious want of durability and general roughness of the contrivance rendered the introduction of various improvements absolutely necessary to enable a pump upon this principle successfully to compete with the other forms of pump at present in use. It was seen at once, for example, that the square wooden box through which the water was raised would have to be replaced by a metallic tube, and that even in the improved kind of cylinder thus suggested the bunch of sheepskin was certainly not the most economic form of piston that could be adopted. The question then which presented itself for the solution of inventors was how to utilize this principle of lifting the water only without any dead weight (for it was admitted that in a properly-constructed pump of this class the descending pistons might be made exactly to counterbalance those ascending through the tube), and at the same time reduce to the minimum the friction between the tube and pistons, as well as that about the wheel by which the pistons were put in motion.

To the solution of this question inventors have energetically applied themselves during the past century, the first real progress being that made in the chain-pump, invented in 1790, by Mr. Deprony, who used an iron tube with a chain running through it, affixing upon this chain at short intervals from each other a series of discs, to which leather washers were somewhat roughly fastened to serve the purpose of packing. The hardening of leather after being in the water, and the impossibility at the date of the invention of obtaining a tube with anything like a smooth interior surface, gave rise to several annoying difficulties in the practical working of the pump—that of steering between too much friction on the one hand, and sufficiently tight packing to prevent the descent of the water when the pump was stopped, being the principle—led to the abandonment of the invention; but not before Deprony had done enough to prove that it was in mechanical details only that the chain-pump was defective. In the ordinary working of the pump a large quantity of water was raised with comparatively little power, but the misfortune was that perhaps at the most inconvenient moment the chain would break, and the whole series of discs would fall to the bottom of the pit, necessitating considerable delay in getting the pump at work again. This, coupled with the annoyance of the pump being temporarily unserviceable if it was left idle for a time, created a prejudice against the system which subsequent inventors have found it difficult to remove.

Notwithstanding this, various efforts have been made to perfect the pump, and it must be admitted that many inventors have made very important corrections of the mechanical defects, not the least of these being those embodied in the invention of Mr. Jules Bastier, which in the hands of an energetic Englishman or American would, no doubt, have realized a fortune, for although the difficulty of the breakage of the chain remained unsurmounted, and the discs were capable of further improvement, there was no question that Bastier had the germ of a good invention, which only required careful development. He recognized the fact that England and America were the most fertile fields for introducing an invention for the more economic raising of water, but with the most contracted notions of a Frenchman, and with such inability to learn our language that after ten years' residence in

England, he could not carry on an ordinary conversation, he sought to develop the invention single-handed, to superintend the manufacture himself, and demanded heavy royalties for the use of the invention; his constant challenge being, until he had reduced himself from affluence to poverty, that he would put down a pump at his own expense, but that if it worked as he promised, he would have his own price for it. From manufacturers who would have undertaken the working of the patents, and had influence to promote the adoption of the pump, he demanded 25 per cent. upon the selling price; the natural consequence being that the invention was neglected until the patents had expired, and the trifling modifications necessary to make the pump a practical success were never brought forward.

But the unsuccessful efforts of Deprony and Bastier have not failed to produce good fruits, and it is now confidently believed that the last of the mechanical defects which have hitherto prevented the general adoption of this principle of pumping have been removed. Mr. Francois Martin, of Rue Laugier aux Ternes, Paris, an ingenious mechanician, who has had considerable experience in the actual manufacture of pumps of this class, and has, therefore, had the best possible opportunities of observing the defects, and judging of the readiest means of removing them, has constructed working models of pumps upon the principle of the chain-pump, but in which the inconveniences referred to—the breakage of chain and defects of the pistons—are entirely overcome, and he is now seeking the assistance of an English or American capitalist to join him in securing the necessary patents. The action of the model is as near as may be perfect. The system which he uses for the packing of the pistons is admirable, since there is scarcely more friction than in the best form of steam-engine cylinder, although they are sufficiently tight to hold up the column of water for many hours. With material of ordinary quality it is most unlikely that any breakage would occur between the pistons more frequently than the breaking of the piston-rod of a steam-engine, while in the possible contingency of such a breakage the pistons would not, as in the chain-pump, fall to the bottom of the pit, but the evil could be remedied in five minutes. These facts, coupled with the circumstance that the pump can be cheaply constructed, should suffice to ensure its general introduction.

THE VALUE OF SUPER-HEATED BLAST IN THE WORKING OF BLAST FURNACES.

Translated from the German of Prof. Tunner by Mr. H. Rocholl.

"Journal of the Iron and Steel Institute."

Most metallurgists remember that on the first introduction of hotblast in the working of blast furnaces, the temperature of the same, taken at the tuyeres, amounted from only 150 degs. to 300 degs. C. (302 degs. to 572 degs. F.) Nevertheless, a saving of 15 to 30 per cent. and more of fuel was everywhere experienced, and the only objection against the use of heated blast was the circumstance that, in some instances, the saving of fuel was accompanied by a deterioration of the quality of the pig iron. Chemical analysis has proved a larger amount of silicon to be the cause of this pig iron being objected to. In all probability, this higher percentage of silicon results from the circumstance that heated blast produces a higher temperature, particularly of the lower part of the furnace, where the reduction of silicon takes place. The first and most natural means to diminish the temperature of the lower parts of the furnace, and to obtain conditions similar to those when using cold blast, was found in the increase of burden; but it appeared that this did not effect in all cases what was desired; in several instances a perfect reduction and the desired degree of carburization were not obtained. The limits of those conditions under which the pig iron is grey or white seem to approach each other so closely that, for a long time, particularly in Inner-Austria, metallurgists doubted whether heated blast could be advantageously used for a regular production of white iron. After a closer study

of the blast furnace process, however, another remedy against an excessive formation of silicon was found, which did not impair the reduction and carburization of the metal; a more basic slag, obtained by an additional quantity of limestone, appeared to have a firmer hold of the silicon, and to prevent its entering largely into the pig iron. This expedient is employed successfully in all those cases in which the ore does not already contain an excess of lime, for, by the presence of a large excess of lime, sulphur enters into combination with this earthy base. In some few cases, a widening of the crucible, or lowering of the pressure of the blast, is found useful; these expedients, however, are applicable only within narrow limits prescribed by other conditions. In all those cases where an increased proportion of silicon is not objectionable, but rather desired, the above-named means of reducing its amount are of course not used, and the introduction of heated blast under such conditions was, from the beginning, followed by the greatest success.

At the present time, hot blast, in consequence of the saving of fuel it effects, is of so universal application, that only exceptionally a blast furnace worked with cold blast is met with; but another question recently has arisen and is discussed eagerly among scientific and practical metallurgists, viz., the highest temperature at which an increased heating of the blast would be accompanied by increased economy. In England, ever since Neilson in 1827 introduced hot blast, a higher temperature has been worked with than in any other country. From England, particularly from the Cleveland district, recently has originated a considerable enlargement in cast iron hot blast stoves, as well as the introduction of Cowper's and Whitwell's stoves, by means of which iron smelters have been enabled to convey a blast of 500 degs. to 800 degs. C. (932 degs. to 1,472 degs. F.) into the furnace. In the same district particular attention has been paid to a scientific investigation of the blast furnace process, most prominently by Mr. I. Lowthian Bell. In England consequently, this question has originated, and there, most probably, will it first be decisively solved. This circumstance, however, does not exclude this matter from being again discussed in this place.

The majority of English metallurgists and iron smelters, according to the papers and discussions reported in the *Journal* of the Institution of Civil Engineers, pronounce the highest possible temperature of blast to be most economical, or at least they are of opinion that the limit beyond which increase of temperature does not increase economy has not yet been reached, still less exceeded. The other party, which believes that this limit has already been passed, at least in the Cleveland district, is headed by Mr. I. L. Bell, and for this reason their views call for closer criticism, as Mr. Bell recently has directed more attention and labor on the study of the blast furnace process than any other metallurgist.

A final settlement of this question is made more difficult by the circumstance that the consumption of fuel is influenced not only by the temperature to which the blast has been heated, *i. e.*, by the quantity of heat which it conveys into the furnace, but also by the dimensions of the furnace, which determine the degree to which the heat, conveyed into and generated in the furnace, is utilized. Not only the temperature of the blast, but, at the same time, the capacity of the furnaces has, of late years, been largely increased; consequently, it is difficult to make out for certain how much of the saving in fuel is due to the higher temperature of the air, and how much to the increased capacity of the furnace. If, besides, the material (ore and fuel) operated upon, or the quality of the pig iron, has changed, it will be still more difficult to assign to the increased temperature of blast its due share of the saving of fuel.

I shall begin by giving a short account of the opinions, investigations, and experiences, the publication of which has caused Mr. I. L. Bell to be acknowledged as one of the leading metallurgists of the present day.

Mr. Bell, in order to make out his case, assumes a blast furnace so large that the charge on going down may absorb the sensible heat of the gases, as well as saturate them with oxygen from the ore, as completely as is compatible with the nature of the blast furnace process. When in such a furnace the cold blast is changed for hot, say 485 degs. C. (905 degs. F.), it seems clear that, as far as intensity is concerned, the same should take place in a larger as in a smaller furnace, and the same extraordinary consequences should be

looked for, if really they were depending on the increased intensity. This, however, is not the case, for if the furnace is so large that it affords the time required for finishing in proper time the two processes of reduction and smelting, a unit of heat, entering it by way of the blast, cannot be more effective than a unit generated in the furnace itself by combustion of fuel.* According to Mr. Bell's view, it is therefore much simpler, and consequently more economical, to burn the whole of the fuel in the furnace itself with cold blast, instead of burning part of it in a stove, and heat the blast. In that case only, according to this theory, an advantage is to be gained by heating the blast, if it is done by a less valuable fuel which cannot be utilized in the furnace itself, *e. g.*, the furnace gases, or by impure and less expensive small coal, etc.†

This practically is the case, particularly as the furnace gases are universally used for the purpose; the question remains to be answered up to what extent the combustion of the expensive furnace fuel may economically be replaced by the heat of the blast.

The chemical laws according to which the power of CO of reducing oxides of iron diminishes in presence of CO_2, which acts as an oxidizing agent, establish a limit beyond which an increased temperature of blast is useless; with the increase of heat necessarily the proportion of CO increases, which is supplied by the combustion of fuel. Mr. Bell has shown by experiments that at 300 degs. C (572 degs. F.) a mixture of 100 vol. CO and 50 vol. CO_2 is indifferent to oxide of iron, as it occurs in calcined Cleveland ore, while the same quantity of CO mixed with 45 vol. CO_2 effects a partial reduction of the oxide of iron. This latter mixture, however, at 600 degs. C (1,112 degs. F.), has no longer reducing but oxidizing properties.

Mr. Bell, in consideration that the chemical action of this mixture is only slow, and the temperature increases downwards, assumes that a saturation of the gases with oxygen, to a degree corresponding to a mixture of 45 vol. CO_2 and 100 CO, does practically not take place, and he fixes for calcined Cleveland ore a proportion of 40 vol. CO_2 to 100 vol. CO as that at which no more oxygen is taken up. Mr. Bell calculates that for an ore which yields 40 per cent. and requires 15 cwt. of limestone per ton of pig iron, 93,000 calories are required per ton of pig iron.*

* No. 1.—In the zone of fusion :—		
Fusion of pig iron	6,600	
Do. of slag	17,000	
Decomposition of H_2O in blast	2,800	
Reduction of P_2O_5, SiO_2 and SO_3	4 000	
Expansion of blast	4,050	
Radiation from walls	450	
		34,900
No. 2.—In the zones of heated absorption, transmitted ... through the walls of the furnace.....	2,500	
No. 3.—In the zone of the decomposition of limestone :—		
Expulsion of CO_2.....	5,750	
Decomposition of do.....	5,760	
		11,310
No. 4.—In the zone of reduction :—		
Reduction of Fe_2O_3	33,100	
Carbon impregnation.....	1,440	
Evaporation of water in coke.	300	
Radiation from walls.....	650	
		35,490
No. 5.—Carried off in gases....		8,800
		93,000

To generate these 93,000 calories by cold blast at a proportion of 40 vols. CO_2 to 100 CO in the escaping gases, 25½ cwt. of good Durham coke are required Now, as this proportion of CO and CO_2, calculated from the amount of oxygen to be removed from the ore, requires only so much carbon as is contained in 21 to 21½ cwts. of coke, it follows that 4 out of these 25½ cwts. may be saved if the heat (represented by those 4 cwts. of coke) is conveyed into the furnace by way of the blast. This is accomplished by heating the latter to about 485 degs. C. (905 degs. F.) What, however, will be the result when the blast is introduced into the furnace at about 800 degs. C. (1,472 degs. F.)? Evidently this additional heat will increase the temperature of the whole contents of the furnace, and on reaching the zone of reduction, will enable the CO_2,

* Nothing can be said against this; on the contrary, the general abandoning of Cabriol's hot blast stove confirms this view. Quite different, however, are the conditions when the blast introduces only the heat, not the products of combustion, from the stove into the furnace.

† The advantage to be gained by the more perfect combustion obtainable in stoves compared with the combustion in the blast furnace (which yields more CO_2) cannot be of much consequence, it being counterbalanced by the considerable amount of heat escaping in the waste gases of the stoves and lost by radiation between the stove and the tuyeres. More important is the convenience which changing the temperature of the blast affords for quickly regulating the working of the furnace.

which was inert at the lower temperature, to take up carbon in the now increased temperature.

This gasification of carbon in the zone of reduction, and consequent diminution of the quantity arriving in the zone of combustion, will again lower the temperature of these two zones, and, finally, as the excess of heat conveyed into the furnace increases, the proportion of CO_2 in the furnace gases will decrease. Mr. Bell always has found proof of these reactions in his investigations on the subject, and he shows, from the results of a furnace at the Barrow Iron Works, and some furnaces of the Middlesbrough district, that the highly-heated blast from Whitwell stoves, compared with blast heated to only 450 degs. or 500 degs. C. (842 degs. to 932 degs. F.), did not effect any further economy of fuel.

Mr. Bell admits brick (Whitwell) stoves to possess considerable advantages over cast iron ones, but for sufficiently large furnaces he does not put any value on their power of giving constantly a temperature of 500 degs. C. (932 degs. F.), simply because such a high temperature is useless. If, however, the particular nature of certain ores or fuel necessitates the use of small furnaces, the more highly-heated blast proves a valuable help. The power of the blast furnace gases of taking up oxygen reaches, according to Mr. Bell, its limit when 30 per cent. of the CO are transformed into CO_2. Consequently, when this proportion is reached, further economy ceases, as they have no further reducing power.

From Mr. Bell's lengthened experience, it appears that a furnace 80 feet high, and of a capacity of 12,000 to 16,000 cubic feet, has all the advantages which can be gained by increasing its size; furnaces of a capacity up to 41,000 cubic feet, which lately have been erected in the North of England, have not realized corresponding advantages. According to Mr. Bell, in a furnace of 16,000 cubic feet, the limit is reached to which the waste gases may be cooled and saturated with oxygen; nor does the production of pig iron keep pace with the increasing size of the furnaces, as is evident from the following data:—

Cubic capacity of furnace, in cubic feet ...	6,000	12,000	16,000	26,000	41,000
Weekly production, in tons	220	260	350	400	550
Weekly production per 1,000 cubic feet, in tons	37	23	22	16	13

I mention one more statement which Mr. Bell has experimentally proved. As the quantity of heat carried away by the waste gases is represented, even with the largest furnaces, by 2 to 3 cwts. of coke per ton of pig iron, Mr. Bell, in order to gain a better insight into the circumstances affecting the temperature of the upper part of the furnace—termed by him the zone of reduction—has made the following experiment: He replaced in a regularly working furnace the burden of calcined ironstone by an equal weight of slag and flints, a mixture perfectly neutral to CO, and continued this mode of charging for many hours. The result was an immediate fall in the temperature of the gases, and subsequent rise as soon as calcined ironstone was again charged. This experiment seems to prove that, in contradiction to the usually adopted assumption, a development of heat takes place in the reduction of oxide of iron.

As the work of the blast furnace consists not only in the smelting of the charge, but, at the same time, or rather previously, in the reduction of the oxide of iron and immediate carburization of the iron produced, it is clear that for the performance of these processes a certain weight of fuel is necessary. Now, if it be universally correct that the power of the blast furnace gases of taking up oxygen, without simultaneously re-oxidizing reduced iron, ceased as soon as they contained 40 vol. of CO_2 on 100 of CO; furthermore, if in the large furnace the reduction of the ore really be completed at a temperature of 400 degs. to 500 degs. C. (752 degs. to 932 degs. F.), nothing could be said, in my opinion, against Mr. I. L. Bell's theory and calculations, at least as far as it concerns the production of white iron. But a much larger proportion of CO_2 exists in the gases from our furnaces which smelt easily reducible ores by means of charcoal, as is shown in Messrs. R. Richter and R. Shœffell's analyses published in this journal (Berg-und Huettenmaennisches Jahrbuch), and the reduction is completed at a much higher temperature, below the boshes, as well as in our furnaces, according to Prof. Kupelwieser and Schœffell's and my own observations, as in the Swedish charcoal furnaces, as shown by M. Rinman. This latter statement that the reduction is completed at a higher

temperature of 800 degs. to 1,000 degs. C. (1,472 degs. to 1,832 degs. F.) is corroborated by Dr. C. W. Siemens, at least for the denser kinds of iron ore, *e.g.*, magnetic ore. Mr. Bell himself, in his several publications on this subject, has repeatedly stated that his calculations in the first instance refer only to Cleveland iron ore. Under these circumstances the discussion of the economical value of super-heated blast does not seem a superfluous one, notwithstanding Mr. Bell's most valuable work on the subject.

I first will try to show by calculation that the proportion of Co_2 to CO in the waste gases of our furnaces must be considerably higher than 40 vol. of the former to 100 of the latter, corroborating Messrs. Richter and Schœffell's analyses, the correctness of which from some sides has been doubted.

Adopting Mr. Bell's mode of computation, calculate the quantity of heat absolutely necessary for the production of 1 ton of white pig iron in the Inner-Austrian charcoal furnaces as follows:—

	Units.
1. Evaporation of water in charcoal.....	400
2. Reduction of ore and carbon impregnation.....	32,400
3. Decomposition of moisture in blast.....	1,600
4. Heating and fusion of pig iron (Rinman).....	6,800
5. Do. of 14 cwts. of slag (Rinman).....	6,160
6. Reduction of silicon and other impurities.....	1,000
7. Transmission of heat through walls of furnace and heating of tuyere water (Bell).....	3,840
8. Heat in waste gases, escaping at a temperature of 300 degs. C. (572 degs. F.	6,600
	58,800*

This quantity of heat is generated, the furnace working regularly and with a blast of 300 degs. C. (572 degs. F.), by a charge of 14 cwts. of charcoal, containing about 12·6 cwts. of pure carbon. After deducting ·9 cwts., as the quantity taken up per ton of pig iron, there remains available for combustion 11·7 cwts. of carbon.

	Units.
This quantity on burning to CO yields 11·7 248 =	29,016
60 cwts. of blast of 300 degs. C. yields ·237 × 60 + 300 = ...	4,266
Total	33,282
The required quantity was	58,800
Leaving to be supplied by combustion of CO to CO_2	25,518

* This figure is more likely too low than too high, the absorption of heat by expansion of the blast not being taken into account. The quantity of this certainly amounts to more than the heat, which, as Mr. Bell has proved, is generated in the reduction of the ore, and which has been neglected in this calculation.

In order to generate this heat $\frac{25518}{2400} = 10{\cdot}64$ cwts. of CO have to be burnt to CO_2. Now the above 11·7 cwts. produce 27·30 CO, so that after deducting 10·64 there remain unchanged 16·66 cwts. CO. Consequently, in order to generate 58,800 units, 16·66 CO and $10{\cdot}64 \times \frac{22}{14} = 16{\cdot}72$ CO_2 or by volume 64 CO_2 on 100 CO) have to be formed. Herr Schoffel found, in 1871,* 58·3 CO_2 on 100 CO; Herr Richter's analysis of 1859 shows even more CO_2 than CO. We certainly may conclude that the proportion of 40 CO_2 to 100 CO, on which Mr. Bell's calculations are based, cannot be universally accepted as true.

If, as Mr. Bell assumes, the reduction of oxide of iron be effected only by CO, and the whole of the iron brought into the furnace in the state of Fe_2O_3, the redution of 19 cwts. of iron would require 14·2 cwts. of CO and produce 22·2 CO_2, while, according to the above calculation, the generation of the necessary heat requires only the formation of 16·72 CO_2. If, in the process of reduction, 22·2 cwts. of CO_2 were formed, the weight of CO remaining, at a consumption of 14 cwts. of charcoal, would be only 13·1 cwts., consequently 108 vols. CO_2 on 100 CO would result, a proportion which, by the late Prof. Richter, has actually been shown to exist in the gases from the Wabna furnace at Eisenerz.

However doubtful it may seem, after more recent investigations, whether such a large proportion of CO ever does occur in furnace gases, certainly there can be no doubt that in the working of our blast furnaces for white iron, under the conditions on which the above calculations are based, the reduction of the ore demands the formation of a larger quantity of CO_2 than the generation of the heat required for the smelting necessitates, and consequently that, in accordance with Mr. Bell's theory, a higher temperature of the blast cannot be accompanied by a greater saving of fuel. It seems a vain endeavor exactly to fix the highest temperature at which, in our production of white iron, the heating of the blast is accompanied by a corresponding saving of fuel; the doubt which still exists about the conditions under which the re-

* Berg und Huettenmaennisches Jahrbuch of 1873, p. 188.

duction of the oxides of iron takes place, does not allow the assumption of incontestible bases for calculation; however, so much seems almost certain, that at a temperature of 300 deg. C. (572 deg. F.), the limit is not only reached, but most probably passed. Thus the erection of the more expensive hot blast stoves (large cast iron ones, or Whitwell's), for our blast furnaces in the production of white iron is only so far of advantage as the temperature of the blast, which can be regulated at will, and raised very high, affords a convenient means of regulating the work of the furnace.* Very different, however, are the conditions under which grey iron is produced in Inner-Austrian blast furnaces, respecting which, since the introduction of the manufacture of the deep grey Bessemer iron, several valuable observations have been made.

In Neuberg formerly, at a temperature of blast of 200 degs. C. (392 degs. F.) and a yield of 44 to 45 per cent. of pig iron, 15·4 to 15·6 cwts. of charcoal were used per ton of white iron, and 23 to 24 cwts. per ton of grey iron, *i. e.*, 50 per cent. more fuel was consumed for the production of grey Bessemer iron than was used for white. Lately, by heating the blast to about 500 degs. C. for the production of Bessemer iron, the consumption has been reduced to 19 to 20 cwts., a saving of more than 25 per cent. against the weight required at a lower temperature. In the Carinthian blast furnaces at Loelling, Treibach, and Heft, many years since, only 12·6 to 14 cwts. of charcoal were used per ton of white pig iron, at a temperature of blast of 160 degs. to 200 degs. C (320 degs. to 392 degs. F.) and a yield of 50 to 54 per cent. At Treibach, a further economy of fuel on using hotter blast has been asserted, but afterwards doubted; only so much is certain that the quality of the white iron produced at a temperature of blast of 500 degs. C. (932 degs. F.) has been by all consumers objected to, and its production has been accompanied by many irregularities. For the production of grey Bessemer iron of first-rate quality, however, at Heft, the consumption of charcoal has been reduced from 20 cwts. and more at 200 degs. C. (392 degs. F.) to 17 to 18 cwts. at 350 degs. to 400 degs. C. (662 degs. to 752 degs. F.)

It seems certain that at Triebach, when with the use of highly heated blast the burden was considerably augmented, in order to avoid the formation of grey iron, a perfect reduction did not take place, in consequence of which, what is called a boiling slag (Kochschlacke) formed in the crucible of the furnace. In consequence of the boiling the pig iron grew porous, intermixed with slag, though still of a greyish character, owing to the high temperature at the tuyeres. At Heft and Neuberg, however, in the production of grey iron with a consumption of 17 to 20 cwts. of charcoal, even at a high temperature of the blast, the quantity of CO required for complete reduction is present in sufficient quantity.*

This difference in the value of superheated blast for the production of white and grey iron, not at all entered into by Mr. Bell, is of particular importance for our easily fusible, mostly manganiferous ores; for in smelting these ores the difference in the consumption of fuel for the one or the other quality is considerable, and even in the most favorable case the quantity of charcoal required is so large that a deficiency of carbonic oxide is not to be feared.

I believe, in consideration of these facts concerning our charcoal furnaces, that in the smelting of easily reducible ores with charcoal the proportion of CO to CO_2 may reach 60 vols. CO_2 to 100 CO. If in the production of white iron at a temperature of blast of 200 degs. to 300 degs. C. (392 degs. to 572 degs. F.) the quantity of CO_2 in the waste gases does not come up to these proportions, then greater economy may be expected from a higher tempera-

*I must confess that formerly I have put too much trust in several communications which I received as to the saving of fuel, consequent on the use of highly heated blast in the production of white iron. The charge of charcoal being universally measured by volume, I have lately had made exact determinations of the weights of many charges by some of my younger fellow-workers, and so found inaccuracies in several of my former figures.

*I would not by any means dissuade smelters from constructing larger hot blast (cast iron or brick) stoves for our furnaces, which at present are worked for white iron. Such stoves, besides being periodically useful for regulating the working of the furnace, are certainly of greater durability; besides, the demand for Bessemer iron increases annually, and undoubtedly in a short time our iron ores, being so exceedingly poor in phosphorus, will be universally smelted for Bessemer iron, so that the production of white iron, now almost universally practised, will be the exception.

ture of blast, without impairing the quality of the pig iron. A deterioration of the same will in any case be owing rather to a cold working of the furnace than to an increased reduction of silicon, which latter is easily prevented by the means enumerated above.

The considerable advantage of highly heated blast for the production of Bessemer iron above referred to, and proved by the results obtained at Neuberg and Heft, is owing, I believe, not only to the higher consumption of carbon generating an excess of carbonic oxide, which is required for this quality of iron, but no less to the circumstance that in using highly heated blast, the temperature of the upper part of the furnace is relatively lower, and of the lower parts higher than is the case with cold or moderately heated blast. Though I must own that I have not succeeded in proving the increased intensity of highly heated blast in experiments which I performed in the laboratory of the Mining Academy at Leoben, with the assistance of Prof. Kupelwieser and Schœffell, so much, however, is certain, that on using heated blast (unmixed with the gases of combustion from the stove), a higher temperature must exist in the lower part of the furnace than with cold blast, because, in the first case, the same quantity of gas, and equally the temperature of the upper part of the furnace, must be lower, because, with the smaller quantity of gas and increased burden, the absorption of heat must be quicker and more complete. This is proved by the frequently observed fact that in using hot blast, the lower parts of the furnace are more rapidly eaten away than with cold blast. This distribution of the heat is a necessary condition for the production of grey iron, which, when cold blast is used, can only be gained by a greatly increased consumption of fuel.

LIGHTNING CONDUCTORS.

From "The Engineer."

Father Secchi, the well known astronomer and natural philosopher, has recently carried out some very interesting researches on the action of lightning conductors, which deserve some notice at our hands, and the particulars of these researches have been prepared by Mons. G. Duguet, and published by him in the "Bulletin" of the last number of the *Revue Universelle*. The circumstances we are about to relate took place some four years past at Alatri, where about the same length of time previously lightning conductors had been placed on the two highest points of the cathedral and Episcopal Palace, which crown what we may term the acropolis of the town. It would appear that there was some little difficulty in satisfactorily fixing the conductors, inasmuch as a short distance below the surface of the soil a compact calcareous rock was met with; however, they were eventually placed so that they had penetrated to a depth of four metres, and were furnished with barbed points, five centimetres wide, five millimetres thick, between which was twisted a strong copper wire, with the object of increasing the contact between the conductors and the charcoal in which they were immediately immersed. The inferior portion of the conductor, to the length of one metre above the surface of the earth, was of copper, at which distance it was united to the iron in a box placed in the lower part of the building; the gutter in which wires were laid was five metres long, with a section of sixty centimetres, and was carried as far as the roots of some neighboring trees, where it was anticipated the soil would always contain a certain amount of moisture; and the bottom of this gutter had a bed of pulverized charcoal twenty centimetres thick. It is to be understood that the separate conductors in the belfry and choir were connected by a bar of iron, with the object of giving, in case only one point was struck, the fluid the facility of two roads of escape.

The effect of these arrangements was so far satisfactory that, although the belfry was four times touched, no damage whatever ensued, until, on the night of the second of November, 1872, a terrific storm burst over the town, when the belfry was struck twice without any harm resulting, and again a third time with the effects we are about to relate, premising, however, that about four years previously cast iron

piping had been laid down for the water supply of the villages of Alatri and Ferentino, and the distributing apparatus for the same was placed in a building but a few yards distant from the belfry; there was, however, no communication between the piping and the conductor.

We now come to the facts. At the third discharge on the night in question the electric fluid, starting from the lower end of the conductor, struck across towards the line of pipes leading to Alatri and Ferentino with the following effects:—(1) It ploughed out a trench, throwing up the earth regularly on either side in a straight line for a length of about ten metres and seventy centimetres deep; starting from the lower end of the conductor towards the water pipes leading to Ferentino, crossing a wall, and considerably damaging the corners of the building. (2) It followed the line of piping, destroying it and driving some of the fragments to a distance of nearly eighty centimetres, the lead in the pipe-joints being melted, and the water of course, ceasing to flow towards Ferentino, spread itself over the building. (3) Another portion of the fluid, passing on to the pipes leading towards Alatri, crossed a reservoir, driving out with force some wooden plugs, passed then into another reservoir situate in the town, twisting in a most extraordinary manner, a sheet of lead, and then, having committed other damages, escaping by the feed-pipe of a public fountain. (4) On examining the point of the conductor it was found to be blunted, and it was impossible to unscrew it. This point was melted in such a manner for a length of three centimetres that its diameter at the end, which seemed to have been cut short off, was only one centimetre. The gilding had almost entirely disappeared. The church itself was not, however, in the slightest degree injured.

What strikes us first of all in the foregoing is the large quantity of the electric fluid which must have been present, and the immense force of its discharge. It does not, however, appear that the ploughing of the trench from the bottom of the conductor can be attributed to any direct action of electricity. We incline rather to assign it to the sudden expansion of the moisture contained in the soil; and it should be remembered that Arago is of opinion that this moisture is also the cause of the scar or mark which is noticeable from the top to the root of trees struck by lightning. Secchi follows out the same idea with reference to the rupture of the pipes, which he considers attributable to the sudden evaporation of the water in them, and not to any mechanical action of the fluid. This theory does not, however, appear to us satisfactorily to account for the melting of the lead in the joints. Looking at what occurred in the conduit leading to Alatri, the same distinguished philosopher considers it still more remarkable. He observes, first of all, that the small interruption of continuity between the pipes and the reservoir must have given rise to a leap of the fluid, and consequently to an explosion of vapor, which would account for the deformation of the sheet of lead; and from this he draws the conclusion that the distance, some two hundred metres, intervening between the lead and the building, was not sufficient for the fluid to lose itself in the earth. In fact, the quantity of electricity discharged must have been enormous, for it travelled, marking its passage, a distance of upwards of three hundred metres from the conductor. True, however, that the storm took place after a long period of drought, when, consequently, the soil was in a state but ill-fitted to favor the dispersion of the fluid.

Pursuing the same subject, we find that M. Jaspar, a manufacturer of lightning conductors at Liege, narrates a similar case, which occurred at a chateau in the neighborhood of that city. In this case the wire of the conductor passed against the wall of a lavatory, on the other side of which, exactly opposite to the conductor, was a tap for drawing water which came from a spring some three or four kilometres distant. The lightning hit the conductor, but the fluid, instead of following it down into the well in which the end was plunged, passed through the wall, and struck the pipe on the other side, without however, doing further damage than displacing a few bricks. M. Jaspar, who at the time of fixing the conductor was unaware of the existence of the pipes, cock, etc., on the other side of the wall, offers the following explanation: The well, he says, was probably dry or nearly dry at the time—a suggestion, however, as to which no confirmatory observation was made at the time—while, on the other hand, the cast iron pipes, with metallic joints, sunk n the earth, formed a most excellent means

for dispersing the electricity, and the fluid, as is always the case, quitted the bad to follow the good conductor. It would appear from the foregoing that it is absolutely necessary that communication should be established between lightning conductors and any neighboring masses of metal, especially with water or gas pipes, and also that the greatest possible surface for discharge should be made available. This surface in the conductor of F. Secchi, of which he wrote, was certainly greater than that which Matteuci deems sufficient for the discharge of the conductors of telegraphs, but, as we have seen, it was far from sufficient. Examples of similar actions of lightning to these are not rare in Italy, and Father Secchi mentions the case where the steeple of the church at Lavinia was struck, and the bell melted in such a fashion that the metal ran like hot wax; still he does not consider that this rupture ought to be attributed to any mechanical action of the lightning in the strict sense of the word, although at the same time he admits that the bell, in consequence of the heating of the points through which the electric fluid passed, was subjected to a sudden expansion—an expansion which the surrounding particles could not instantaneously follow, and which hence produced a fracture from almost the same causes as when a glass vase is touched with a red-hot iron. The last point to which he wishes to draw attention is, that as the accumulation of electricity in metallic bodies is in proportion, not to their bulk, but to the area of surface, it is necessary to place not only the gutters in communication with the conductors, but also with the bands of zinc which are frequently used to cover the hips of the roofs; in proof of which the following:—

On the evening of the 26th July, 1870, says M. J. Muller, of Fribourg, during a severe storm the lightning struck a large three-story high building, on which were some reflective conductors. Two of these were placed at the extremities of the ridge of the roof, and united together by a bar of iron, from the centre of which the conductor started, which, after having been prudently placed in communication with the gutters, was carried down to the ground. These gutters were furnished at different points with descending pipes for carrying off the water, which reached almost to the earth. The ridge as well as the hips were covered with bands of zinc, on which were immediately placed the stalks of the conductors; but there was no communication established between the bands of zinc and the pipes, nor between these and the ground, and in this lay the defect. So long as lightning finds substances which are good conductor, such, for instance, as bars of iron, it follows them without doing any harm, and it is only when leaving their extremities to seek for other conductors that disastrous effects result. Thus, if the communication we have pointed out had been made, it is easy to imagine that on lightning striking the conductors, the fluid would have been carried to the ground, without causing any damage. But this not being the case, an explosion, in the event of the tension of the electricity becoming sufficiently great was to be expected; and in fact this is what actually did occur on the night of the 26th of July, 1870, when the metallic band was torn in different places, as was also the lower end of the pipe. From this pipe the fluid passed in succession to those for gas and water, breaking them both. A report on this subject was prepared by M. Muller, who pointed out the absolute necessity of establishing communications between the gutters and the bands of metal on the ridge and hips of roof, and also between the descending pipes and the earth. Unfortunately, no attention was given to his warning, although many buildings had conductors deficient in the very ways he pointed out; but the neglect was punished, for on the morning of the tenth of May last year, the lightning under almost similar circumstances struck the buildings at the railway station, Fribourg. The horizontal bar joining the two conductors was shivered, the sheet iron coverings on the hips of the roof and the descending water-pipes were torn and broken; and we have, therefore, another instance of the great necessity for communications being established between the metallic coverings—where these are used—of the ridge and hips of the roof and between the descending water-pipes and the earth, even in those cases where there are no lightning conductors on the building. It is true that in England such accidents are comparatively rare; it is not, however, more than three years back since the tower of a church—St. Saviour's—in the very heart of the metropolis was so struck, and one of the pinnacles knocked off, besides other damage being done; and certainly no

single year passes without something of the sort taking place. The part of the foregoing which, however, appears to us the most important to the bulk of our population, is the necessity which is insisted on of the pipes from the roof gutters being placed in communication with any metal on the roof or in the gutters themselves, and that they be carried down to the dead earth. We think ourselves that this last is the condition of safety most frequently violated, for one has only to notice the rain-pipes as one walks along the streets to have tangible proof that their being carried down into the ground is the exception rather than the rule, and this especially in the suburban neighborhoods. To landlords and builders, then, we especially recommend attention to what we have written. Large public buildings are probably in most cases fairly well protected; but, as we have said, where the rainwater-pipes are the only conductors on a house—and to some extent they are sufficiently effective ones if properly placed—it should be recollected that they should *always* be in communication with any metal on the roofs, and still more should they *always* be in distinct communication with the ground, and not cut off, as is too frequently the case, some foot or so from it.

LIFE-SAVING GEAR.

From the "Nautical Magazine."

A question forcibly engaging the attention of persons interested in ships and seamen at the present time is, whether all seagoing ships should not be compelled by law to carry an increased number, and a superior description of life-buoys, and increased boat accommodation, or other increased or improved means of saving life at sea in emergencies. That this question should command attention now is not to be wondered at. We have endured the agitation consequent on Mr. Plimsoll's well-meant and vigorous book; we have also had harrowing scenes and lamentable loss of life consequent on serious marine disasters; the wreck of the steamship *Atlantic* with a loss of 535 lives; the running down of the *Northfleet*, when peacefully at anchor in a well-known road-stead on our coast, and a loss of 293 lives, and, more recently, the loss of the *Ville du Havre*, a transatlantic steamer that, in defiance of all law and reason, got into the way of a British sailing ship, the *Loch Earn*, and was run down, with a loss of 226 lives. That many of the 1,054 lives lost in these three casualties might have been saved, had there been sufficient suitable, available, and efficient life-saving gear on board, there is no room for doubt. This being so, the fear we now have is not that improved and additional, and even excessive means for saving life will not be provided, but that patentees and ingenious persons will "improve the occasion" with a view to forcing particular inventions on the attention of the public, and that the Legislature may be pressed and unduly pressed, to require that some special invention or arrangement shall be adopted in all ships; and it is because no one invention or arrangement for saving life at sea can be applied indiscriminately to all classes of ships, and to all voyages, that we should at once endeavor, in a calm and quiet way, to inquire whether calamities at sea cannot be classified in such a way as to furnish an indication of the most likely means for saving life in various classes of voyages, and various descriptions of ships and casualties.

To put a case, by way of illustration of the belief that one form of life-saving gear is sufficient, we have only to point to the general impression existing that rafts must always afford a valuable means of saving life at sea. That rafts, even improvised rafts have saved life, there can be no question; but before we can place the raft in a foremost place of saving life in all cases, we must not overlook the circumstances in which they have generally been efficient. We shall then find that fine weather or comparatively fine weather, and sufficient time for launching and stowing, have generally been important elements in the success. Let however, an attempt be made with a raft to save life in a cold climate in the winter, and in a rough sea and far from land and the result would be altogether unsatisfactory. Means that are efficient for saving life in the Pacific, in a beautiful and favorable climate, would be absolutely

worthless in Atlantic winter gales, and would become a means of prolonged torture. Means that would be ample for home trade ships would be of but little use in foreign-going ships, and means necessary for foreign-going ships would be altogether out of place in our coasters. In short, the nature of the voyage or employment of the ship, in the matter of saving life, as well as in the load line, is one of the first points to be considered; the next point is the number of hands, the next the condition of the ship, and the next her construction. For, just as means that would be efficacious in the Pacific would be of but little use in the Atlantic, so certain means for saving life in a small or weak coaster are necessary that are not necessary in large and strong ships; and when the means provided have to be applied, they have to be applied in a different manner and under different circumstances and conditions, in the various classes of ships.

The cases in which means are required to be used from on board ship to save life may be broadly classed as follow:—

1. A man overboard.
2. Assistance required by another vessel at sea.
3. The gradual and steady settling down or destruction of a ship in comparatively smooth water.
4. Sudden and great emergencies, such as being run down, striking on rocks, &c.—*Ville du Havre*, *Atlantic*, &c.
5. Strandings on a lee-shore, as in the case of the *Royal Charter* (loss of 446 lives), *Royal Adelaide*, &c.

The means carried within the ship herself of saving life may be classed as follows:—

1. Life-buoys.
2. Life-mattresses.
3. Life-jackets or belts.
4. Deck-seats, and other movable buoyant contrivances, or articles carried on deck.
5. Ordinary common boats.
6. Common boats rendered buoyant as lifeboats.
7. Lifeboats.
8. Rafts.

Having made a general classification of the cases in which means are ordinarily required, and of the means ordinarily provided, we now have to consider which of the means are best adapted to the various cases.

Before we enter on this part of our subject, we must, however, state in plain terms that we are advised, and believe, that in the case of ships carrying a large number of passengers in rough and dangerous passages, or in much frequented seas, it is impossible to provide means for saving all the lives on board in most of the ordinary circumstances attending a casualty. In the mid-Atlantic, for instance, it would be impossible in winter to preserve the whole, or anything like the whole number of passengers, for any considerable time after a foundering where no other ship is near; and even if the passengers could be placed on rafts, they would be without a supply of food, water, and clothing, and would probably succumb to cold, hunger and thirst. We mention this at once lest it should be supposed that in afterwards stating that certain means might be efficacious in certain cases, it should be inferred that we believe that loss of life at sea may be very materially prevented in great wrecks or strandings, or in the case of the numerous "missing" ships from which at present not a soul survives to narrate the cause of loss and the sufferings of the crew.

The first case in which an appliance is wanted on board ship that we shall refer to is, that of *a man overboard*. The readiest and best means of assistance in such a case is the life-buoy; but it should be capable of floating high in the water, and be of light color, so that it is easily seen by day, and it should at night be thrown over with one of Holmes's lights attached. These lights float on and actually burn the water as fuel and last for forty-five minutes. We may accept the life-buoy as the first means to be used. The Board of Trade have issued instructions that no buoy is to be passed as a life-buoy that does not come up to their standard. This is a step in the right direction, as the rush and cork-shaving contrivance, formerly in vogue, were worse than useless. We, however, doubt whether the proper form of life-buoy has yet come into use; but we have recently seen some that are under trial, and will, we believe, supersede most others. The life-buoy should never be made fast to anything, but should be hung with a becket and slip toggle, and a proper supply should be carried in passenger ships, and two in every other ship. The life-buoy is of value just in proportion to the speed with which it can be thrown over. But as regards life-buoys, the question naturally suggests itself, why should there not be a large and light buoy in which

a man could jump over, a buoy that might serve as efficiently as a boat? The only difficulty is in finding a material of which such a buoy can be made. When a suitable material is found, the difficulty vanishes. Something light and, at the same time, practically indestructible is wanted. Before we pass from the subject of the life-buoy, it is well to state that any contrivance that requires inflation, or pulling out, or stiffening before it is used, is altogether beyond serious consideration. Anything to be used as a life-buoy must be kept as it is to be used. We may concede that the life-buoy is the first means for use in case of a man overboard, or a boat capsizing alongside, &c., and that it is, if properly constructed, well fitted for the purpose, and that all ships ought to carry them.

Life-mattresses are the next contrivance for consideration; and as the attention of several practical men has been devoted to them, they require more than a passing notice. Some of these mattresses are exceedingly good in design; for instance, those of Admiral Ryder and Capt. Forster. Others are bad. But, our objection to mattresses as a universal remedy for loss of life at sea is, that they are not calculated to meet sudden and great emergencies, as they must be kept below one or two decks in passenger ships; and that when the emergency is not sudden there are other and better means of saving life. In coasters, with few hands and in ships of the Royal Navy where there is discipline and cleanliness, these mattresses would be valuable. But, on the other hand, where means are most wanted they are unsuitable.

In the case of the *Atlantic*, the master stated. "The first intimation I had of anything was the ship striking on Marr's Rock. The officers were quickly at their stations, accompanied by the quarter-masters. The first sea swept away all the port boats: and the ship heeling over rapidly soon rendered the starboard boats useless. Every effort was made to send the people forward outside the ship; but the short time defeated all our efforts. A lifeboat rolled over in a few minutes, carrying with her thirty or forty men. Communication was at length established by a rope with a small outlying rock, forty yards distant. The largest number of saloon passengers lay near the main-rigging, and died. We encouraged, as much as we could, about 450 people on the ship's side to keep moving about. In many cases they gave up entirely, and died apparently without pain. Twelve men, clinging together, lay down beside me, and notwithstanding all efforts to rouse them, died and slipped off into the sea." This sad case is about the best illustration we can give of the combined effects of fear and cold; and it also shows the utter uselessnes of boats in such a case. The hold was full of water, and even if there had been cork mattresses below they could not have been reached.

As regards the *Ville du Havre*, one of the reporters stated:—"The chances of saving life would have been extremely small even in the daytime, with possibly a large proportion of the whole number of those on board upon deck; but at two o'clock in the morning, with almost every soul except the watch asleep below, these chances were reduced to the minimum. Besides, as our information tends to show, a large quota were women and children, with whom it was almost physically impossible that they should in the brief space allotted to them, have reached the deck. One of the cabin passengers is of opinion that fully three-fourths of those who occupied the handsomely-furnished saloon of the *Ville du Havre* were women and children. Of the 226 who were lost, it is thought that by far the greater portion, probably five-sixths, never came on deck." "It was only" says one passenger, "when I came up again from the bottom that I noticed any cries. Then I heard a great many persons, who were struggling in the water, crying out piteously for help." Another says: "The bulk of those who were picked up were found floating on the ship's steps or ladders, rafts, pieces of broken yards, fragments of the bulwarks, or timbers of the ship, which they caught just as the vessel passed below the waves, or had enough of consciousness and strength to seize after coming again to the surface." Another says: "Nothing could have saved you except holding firmly by some piece of wreck or life-belt; and most of those on board, I am sure, never came on deck." Another says: After being in water a few minutes I got hold of a buoy, which enabled me to keep afloat for nearly an hour, when I was picked up by one of the *Loch Earn's* boats." And, lastly, another says: "When she was struck, the passengers, as I said, came rushing up from below and began to fill the boats. There were about fifty of them in one of the long-boats

when the mainmast fell on it. Some of them were killed right out, some had their heads smashed, others had their arms and and their legs broken." And, finally, as illustrating the uselessness of the boats in such a case, the French official report states that, "Nothing remained but to save the greatest possible number of lives by means of the boats. The two lifeboats which were on the tackles were the only ones which could be rendered rapidly available; of the six others, two had been smashed in the collision; two more were crushed by the fall of the mainmast and the mizen; finally the last two could not be disengaged in time."

Let the reader think of the confusion and disaster attending sudden calamities in public buildings ashore, the burning of a church or a theatre, for instance, and how persons are crushed, and suffocated, and trampled over in getting to the doors, even when unencumbered by having to convey anything away, and then let him picture to his mind the attempt of hundreds of people, not to rush to doors on a level, or to rush down the gallery stairs, but to rush up a ladder and through a hatchway; and that the attempt is to be made not by persons ready dressed and fully awake, but by people suddenly roused from sleep in a comparatively dark hold. Let the reader think of the suddenness of these wrecks and collisions, that the majority of the passengers are in their berths, and that even to get on deck unencumbered is a great effort, and that the passengers' berths are arranged in tiers one above and behind another. That to get out of bed at all, the majority of passengers would have to climb over others; and then let him think what would be the magnitude of the difficulty if each passenger were to attempt to ascend the companion-ladder carrying his bed. A more complete way of preventing egress from below could not well be devised. It is not too much to say that if the passengers took up their beds many would be killed in frantic endeavors to reach the deck, and that the ship would go down with most of the people below. Our conclusion is against floating-beds, and against any contrivance that has to be kept below and conveyed from below in a sudden emergency in passenger ships. It will either be left below, in which case it need not have been provided, or the finding and securing and bringing of it up will lead to delays and dangers worse than many existing at present. For coasters, however, stranded on a lee shore, or for ships other than passenger ships, especially in cases of collision where one ship stays by the other, these mattresses might enable the crew to take to the water with confidence; but then the question of course arises, are mattresses the best means? This will always be a matter on which opinions will differ, and we should be but too glad if those seafaring men, who discover advantages in cork mattresses, would take the practical step of putting them on board their ships, and seeing that emigrants provide their own beds: there is nothing but cost to prevent them from providing themselves with floating-beds if they choose, and for a floating-bed nothing equals that of Admiral Ryder, made by Messrs. Burt, of Dock Street, London.

Life-jackets and belts are the next appliances we have to consider. Under this head we include all inventions and appliances intended to be attached to the body before taking to the water; we may, therefore include with them, neck rings and chest or back bottles.

Life-jackets are required by the Board of Trade to be provided for the crews of the life-boats carried by passenger ships. The crew manning a life-boat ought certainly to have life-jackets; here, then, is a legitimate use for the life-jacket—and the best, if not the *only* life-jacket for this purpose is that of Captain Ward, R. N., the Chief Inspector of life-boats to the Royal National Life-boat Institution. But, beyond the use of life-jackets for crews of boats, their advocates, like the advocates of mattresses, claim for them an extended use. In the first place, an efficient life-jacket may be better than a life-buoy for a man jumping overboard to save life. This may be conceded; but we then have to come to the further question of providing life-jackets for all the passengers and the crew. The patentees of inventions of this sort, and many persons whose desire to do good is greater than their powers of judging how to do it, will advocate the providing many means for saving life on board ship. Let us, therefore, think for a little on this subject of life-jackets. First, as we have already stated, we do not believe in any means of saving life in great emergencies that is stowed below decks; the only exception to this is, of course, when the means used become, from a close contact with, and fas-

tening to the human body, almost a part of the body. If a life-jacket is to be provided for every passenger, it will be useless in great emergencies, unless the passenger is content to sleep in it, and in that case a cork-mattress would be unnecessary. As regards life-jackets, all those things that require to be "inflated" before they are put on, are of questionable use, although they would be the only things of the sort fit to sleep in. The emigrant's bottle, intended to be strapped on the chest, is more objectionable than the worst form of life-jacket. It would be impossible to sleep with it strapped on, and "to empty out the water, fasten in the cork," and strap on the bottle, in an emergency, would generally be impossible, and, when not impossible, the bottle when on is likely to slip low down round the waist, and expose the wrong part of the body above the water; but, besides this, the presence of the bottle in front of the emigrant would effectually prevent him from assisting infants.

A neck ring made of ox gut, or some such material, and of about the size of a German sausage, was exhibited at the Lord Mayor's *Northfleet* show of models in London, and appeared to be sufficient to keep the head of the wearer above water; but to be of use, it must be worn and slept in at night. It would generally fail in great emergencies, unless worn. Trusting to safety by laying hands in the dark on and then blowing out and then fitting the neck into, a sausage skin, in dire confusion, would be disastrous. When life-jackets *can* be used, is when they are kept on deck ready, and when the persons wanting to use them are on deck and ready to take the water, or can be got quickly on deck. Where their attempted use would end in failure, would be in great disasters, where numerous passengers are below deck at the time of collision or wreck, and where they would either not have time to secure their life-saving gear, or, having, secured it, would be unable to get on deck with it. The cases of the *Captain* and *Atlantic* will illustrate this. We do not, therefore, look for any great saving of life in large and sudden wrecks from the use of life-jackets, or cork-beds; but we do think for coasters and ships not carrying passengers, Captain Ward's life-jackets will be of use and they must be carried.

Deck-seats and movable gear on deck are the next appliances we have to touch on. Under this head we may include all light, or comparatively light, buoyant contrivances—deck-seats, life-buoys, hen-coops, &c., &c. For coasters and ships other than passenger ships, except in very sudden emergencies, we set no store on these buoyant deck articles, for the reason that, where the number of persons on board is much below, or at all events not in excess of, the boat capacity, a good lifeboat is the best, safest, and most comfortable of all means for saving life; and vessels that do not carry passengers can, as a rule, get their boats down and their crew into them. For passenger ships, however, we know of no means so likely to be effectual in sudden disaster as buoyant deck gear. To illustrate our point we have only to refer to the *Northfleet* and *Ville du Havre* casualties. The official report on the loss of the *Loch Earn* states as follows:—"While inquiring into the particulars of this fearful catastrophe, and the terrible sacrifice of life, the attention of the Court has been directed to the fact of the rescued persons, eighty-seven in number, having been saved mainly by means of the floating *débris* of the wreck. The Court would therefore suggest, for the consideration of the Board of Trade, the great desirability of multiplying the means of escape afforded by the floating objects, and the question whether it might not practicable to render the deck-seats or other appliances available as life-preservers by the adaption of the air-tubes or other means tending to so important an object."

This deck gear is, of course, of use only in sudden catastrophes, and then only for a limited time—for such a time, in fact, as will enable passengers to keep afloat until assistance, if moderately near, can be rendered, or until they perish with cold or exhaustion. What is wanted in a sudden emergency, like the *Northfleet* collision, is a quantity of smallish detached buoyant articles on deck, and widely distributed, so that every passenger has a fair chance; rather than one or two large rafts. There is no time to man and lower all the boats, or to get passengers into them; and if they do get into them they are still often killed or drowned. The case of the *Northfleet* furnishes also conclusive evidence that buoyant contrivances that would float off the deck, and could be grasped by struggling passengers, would have been of use. This, case like the cases of the *Alantic* and

Ville du Havre, quoted on page 160, also shows how lamentably boats fail in emergencies. The official report says: "Orders were then given to clear away the boats, and to take the women and children. The lifeboats were forcibly seized by a number of the male emigrants; the port boat was lowered, and shoved off with thirty of them, without a single seaman, without plugs, and only one oar and part of another. No one knew how to manage her; she filled with water, and her inmates shouted loudly for assistance. Others of the emigrants seized the starboard lifeboat, and a struggle ensued between them and a part of the crew for its possesion; eventually, it was partly cleared, the captain's wife one other female, two children, six seamen, and nine of the male emigrants were in her. In lowering her, she got stove by the main sheet bolt, and filled with water. The captain, hearing that she was in a sinking state, ordered the boat's crew to pull off to save their lives. An attempt was made to clear away the remaining boats; their lashings were cut, but before they could be freed from the skids, the ship suddenly foundered (about thirty-five minutes after she had been struck) with her living freight her anchor-light burning brightly when she went down. . . . The steamtug *City of London* (Samuel Kingston, master), was also at anchor the same night, about a quarter of a mile to the westward of the Roar Buoy. At half-past ten rockets were seen to go up to the eastward, about two miles distant. The master at first supposed them to be a signal for a pilot; but subsequently, at seeing others go up in quick succession, believed them to be signals of distress. He at once weighed anchor, and steamed towards the spot, which occupied about half an hour, and when within a cable's length of the ship he saw her go down. The tug was surrounded by people struggling in the water for their lives, and some few were hauled on board. The starboard lifeboat of the *Northfleet* came alongside, partly full of people, who were all taken on board. The mate of the tug and some of the boat's crew put back in the lifeboat, though full of water, with the thole-pins broken, and picked up four other persons from the sea. Subsequently, one of the boats of the *Princess*, pilot cutter, brought four more men, whom she had picked up, and put on board the tug, making a total then on board of thirty-four lives. The pilot cutter, the *Princess*, of Deal, was cruising off the Dungeness of that night; and, on seeing the signals about two miles distant, beat towards the scene. On her arrival, however, the *Northfleet* had foundered. The master of the cutter lowered two boats; the first was manned by the mate (John Stanley) and three seamen, which was sent to the neighborhood of the wreck; the second boat, manned by the steward and three pilots, was sent to cruise about and render assistance to any one floating about. The first boat, after great difficulty, rescued ten men from the mizen cross-trees, which were about 10 feet above the water; they were taken safely on board the pilot cutter. The boat made a second trip, and rescued five men from the main crosstrees; and, in a third trip, rescued six more from the fore crosstrees, making twenty-one souls, including the pilot, Mr. George Brack. . . . ." The only chance is to take the water, and trust to some buoyant object. We have already explained why, in our opinion, life-saving gear carried below deck is not likely to be of use in such a large disaster; we must now point to the difficulties attendant on stowing it on deck. In the first place, any gear so stowed must be secure against heavy seas, and must at the same time be so arranged as to be capable of instantaneous disconnection when wanted. In the second place, it is liable to destruction, as is explained under the head of boats. There is, however, no reason why deck-seats. instead of being almost useless from a life-saving point of view, need not be almost as useful as boats. Nor is there any reason why many things on deck need not be buoyant of themselves. In the "Collins" line all deck-seats were as buoyant as life buoys. But there is a further point. Why should not loose buoyancy be carried in addition to deck-seats and other similar things on deck. Our attention has just been called to a little thing called a "save-all," which we should like to see tried. Sufficient for saving 300 persons can be stowed in a locker, or specially constructed deck-house of 6 feet by 6 feet. Distributed among smaller lockers about the ship, or stowed in the boats, they could be at once used, or, if they were not secured by passengers before the ship went down, they being the first things that would float wide-spread among the passengers, would afford the readiest security for keeping

above water. Shape, no less than buoyancy, is an important element in constructing life-saving gear. We are now, of course, speaking not of saving passengers with boats and a supply of provisions, and conveying them away from the wreck, but simply of the means of keeping all passengers afloat as long as they will live in the water. Such appliances as these, though good for passenger ships where assistance is at hand, would, as we have before said, be useless where no assistance is at hand, and would be unnecessary in ships other than passenger ships provided with boats, and free from the confusion attendant on the presence of frantic women, children, and landsmen.

Ordinary common boats are the next appliances we have to notice; but as these, when carried in large ships, are generally only wanted for ships' use, and, if wanted for passengers' use, are now, as a rule, useless in emergencies, we may dismiss them with one remark—viz., that no boat having a square stern ought to be carried on board a merchant ship, if it is ever intended for use in saving life in bad weather, The Board of Trade will not pass square-sterned boats for lifeboats in passenger steamers, and it would be wise for boat-builders and shipowners to throw over old patterns of square-sterned boats, lest some day they find a useless stock on hand.

As to the means of rendering a common boat buoyant, after the manner of a lifeboat, we have to say, first, that for a ship's boat, solid or granulated cork, or any other solid substance, is just so much dead weight or lumber in the boat; air spaces alone are fit for buoyancy. The Royal National Lifeboat Institution wisely use cork in their boats where it serves chiefly for ballast. Air-casings made of zinc are, of course, wholly inadmissible, and copper is expensive and heavy, and unless covered over with wood is liable to damage. We are only aware of one material that is fit for air casings, and that is a combination of cork between two layers of canvas. For the present, we can only observe that there is no practical reason why a common coaster's boat should not be rendered buoyant, and, for her purposes, as valuable as the best lifeboat. The only thing wanted is the starting of an establishment in which the cork and canvas apparatus could be manufactured quickly, and at such a low price as to bring it within the means of the poorest shipowner. There are no patent rights preventing the use of this combination.

Lifeboats are the next means, and are, of course, the best where they can be used. We are not now alluding to sham things with mock wooden air cases, or rotten zinc or heavy copper tubes, but to really well and substantially-built boats. Messrs. White, of Cowes; Messrs. Forrestt, of Limehouse; and Messrs. Woolff, have built some very fine wooden boats, and the Hamilton Windsor Iron Works have built fine metal boats; but the time has come when we must consider whether good and efficient and insubmergible boats must not be the rule instead of the exception, and whether in this matter of lifeboats for ships we have not been going on the wrong tack altogether as regards efficiency. The fault we find with all lifeboats yet constructed for ships is, that the buoyant apparatus is carried inside the ordinary lines of the boat, whereas a part, if not all of it, ought to be outside. It stands to reason that any buoyant apparatus inside a boat is so much weight, and that it cannot assist in giving lateral stability; and further, that it is of no use until the boat herself is filled, or partly filled with water. Buoyant apparatus is of no use while it is in the air inside a boat, but let it be in the water and it is of use at once. Solid cork puddings or buffers have been used outside boats, but they are not of much use, as their weight alone tends to immerse the boat. What is wanted is a boat with the air buoyancy so far outside as to be of use at once, and so arranged as to give lateral stability. A lifeboat is not wanted to sail a match or to row a match, but is wanted to carry very great weight in the worst weathers, and to be free from the danger of capsizing. We do not hesitate to say that no boat in which the buoyancy is inside the ordinary lines is free from the danger of capsizing. All passenger ships should have lifeboats of the very best model, and all foreign-going ships should render their long boat buoyant as a lifeboat, which can be done effectually at a trifling cost. We regard collapsible boats and rafts and contrivances that require inflating as something wholly beyond serious consideration.

Rafts.—Mr. White, of Cowes, has a bridge-boat, and latterly we have seen

several other contrivances for using the upper part of a bridge or the top of a deck-house as a large pontoon raft; but none of these we have seen yet can, as well as being readily let go, be also securely fixed against the action of heavy seas. The floating off of a whole deck-house as a raft or "ark" has over and over again been proposed, but nothing really practical has come of it. For rafts we are therefore at present reduced to those that must occupy boat space. The best we have seen is the lifebuoy boat designed by Captain Murray and Mr. Gray for coasters; but seeing that it is impossible for steamers to carry more boats than they do at present, the question yet remains, how far rafts ought to be carried in addition to boats. That they might with advantage be carried in lieu of some of the present boats is on all hands admitted, but the difficulty for owners to settle is what form of raft to carry, and how to stow it. No one can, for a moment, doubt that really efficient lifeboats and really efficient rafts would sometimes materially assist in saving life, because they would not hurt by being stove. Common boats can never be of immediate and great use in exceptional cases like the *Ville du Havre*. A raft, of course, can have the advantage over a lifeboat, that, whichever way it falls in the water, it turns up right; it has also, if properly constructed, the advantage over a common boat, that it will not turn over: but a good lifeboat, constructed on the plan we have suggested, has one advantage over everything else for ordinary purposes, and that is, that it can carry in comparative comfort all the persons it takes on board, and that passengers in an insubmergible and well-appointed lifeboat might find shelter and protection from sea for a longer period than they could get by anyother appliance for saving life.

Our practical conclusions are—

1. That for coasters, and short over sea trips, two good lifebuoys, a life-jacket for each of the crew, and buoyancy in a boat or in a raft, are all that is necessary.

2. That for foreign-going ships, other than passenger ships, instead of the four, five, or six, or seven boats they are now required by law to carry, on or more good boats, with sufficient buoyancy, and one or more good rafts, according to the size of the ship, two or more lifebuoys, and four life-jackets are sufficient. At present they and coasters are alike required to carry boats according to their tonnage.

All sailing ships, not carrying passengers, are required by law to carry boats as follows, viz.:

Under 100 tons register	1 Boat—14x5x2.2ft.
Above 100 and under 200 tons register*....	1 Boat—14x5x2.2 and 1 Boat—16x5.5x2.75
Above 200 and under 400 tons register.....	1 Boat—14x5x2.2 1 Boat—20x6x3
Above 400 and under 600 tons register.....	1 Boat—16x5.5x2.25 1 Boat—22x5.5x2.5 1 Boat—22x6.5x3.25
Above 600 and under 800 tons register.....	1 Boat—16x5.5x2.25 2 Boats—24x5.5x2.5 1 Boat—25x7x3.5
800 tons register and upwards.....	1 Boat—18x5.5x2.25 2 Boats—24x5.5x2.5 1 Boat—26x8x3.33

All steamships, that do not carry passengers, are required by law to carry a full complement of boats, the same as steamships carrying passengers. Thus, an ordinary steamship, say of 1,000 tons, carrying merchandise, and not carrying a single passenger, is required by law to carry seven boats. These seven boats are as follows One boat of $18 \times 5.5 \times 2.25$, $\times$ 2 boats each of $24 \times 5.5 \times 2.5$, + 2 boats each $22 \times 5.5 \times 2.5$, +2 lifeboats each 28 feet $\times 8.5 \times 3.5$: or they may substitute a launch $27 \times 8.5 \times 3.3$, for the two boats of 22 feet long.

The evidence on the subject of boats, given by the (Marine) Assistant Secretary to Board of Trade, is as follows:

Question "10,554 (Mr. Rothery). You know the 294th Section of the Merchant Shipping Act, which says, "No officer of Customs shall grant a clearance or transire for any ship hereinbefore required to be provided with boats or life-buoys unless the same is duly so provided?"—Yes.

"10,555. Did you call upon the Customs to enforce that clause?—About five years ago the Customs were called upon to enforce that clause, and they sent out a circular to the collectors, and tried to enforce it.

"10,556. What was the result?—The result was that the whole trade was stopped.

"10,557. Actually stopped?—Actually stopped."

"10,559. The Customs advised you that it could not be enforced?—They did."

* In sailing ships, not carrying passengers, of 150 tons register and under, a substantial boat of sufficient capacity may be substituted for the two boats named.

Instead of all the boats required by law, it would be wise to have boats and rafts with *buoyancy* sufficient for the crew.

3. For passenger ships, it is probably wise to provide additional buoyancy of the "save-all," or life-preserving class, safely and securely stowed, with a view to meeting sudden calamities; a few good lifeboats that will not turn over, and a few good rafts or deck-house roofs for casualties that are not sudden. The boats should be carried at davits, and the rafts at davits, or conveniently elsewhere; but, as to the number of boats, it is impossible to provide more accommodation than at present.

In conclusion, it is well to bear in mind that gear carried on deck is liable to destruction before it can be used; such is the force of the sea in the Atlantic trade, that the boats in the chocks above the decks of large steamers, high up out of the water, are sometimes broken to matchwood, and that, although life-saving gear to be of use in emergency must be carried on deck, it is exposed to destruction in some trades, and may therefore be of but little use. Another point is, that to cumber the deck with appliances is to lead to danger by causing difficulties in navigating a ship. The providing of life-saving gear is, after all, not so simple a subject as many inventors and humanitarians would make out.

BOILER EXPLOSION AT THE LINTHORPE IRON WORKS.*

The author commenced by referring to a paper he had read at the meeting of the Institute held at Merthyr-Tydvil in September, 1870, upon "the efficiency and durability of plain cylindrical boilers." He had then pointed out that one-fourth of 'all insured boilers were of the plain cylindrical type; that they continue to be preferred by many engineers, and especially for the utilization of the heat, derived from the combustion of blast furnace gases; and that they were specially liable to danger from "seam rips." He had shown that one great cause for this arose from their being usually suspended rigidly from more than two supports; and had proved by a long series of experiments upon pieces of boiler plate, alternately heated and cooled like the bottom of a boiler, that a permanent contraction of the latter must always eventually ensue, causing a seam rip and possibly an explosion. As an antidote, he had advocated the suspension of long horizontal boilers upon volute springs, which would permit a change of form according to alterations of temperature, without materially relaxing or increasing their support. Since that time he had had three boilers, so mounted, work with marked success, but the experience derived from them had led him to further improvements. During the same interval many boilers rigidly mounted had also been at work; and one of these recently exploded at the Linthorpe Iron Works, causing great damage, but fortunately no loss of life. It was because he considered all such boilers unduly strained, and in constant jeopardy, and because he thought he could now show the way to make them perfectly safe, that he ventured to call renewed attention to the subject. Some owners of steam power objected to be involved in any public discussion of the details of a disaster which might have befallen them. Messrs. Lloyd & Co., on the contrary, at once yielded their cordial consent to the proposal, that all possible experience should be derived by the members from their misfortune; and gave the writer *carte-blanche* to visit, and examine their steam machinery, and to investigate the circumstances attending the explosion; and at the same time expressed an earnest desire to adopt improved appliances if only such could be found. The exploded boiler was insured with the Midland Steam Boiler Inspection and Assurance Co.; and Mr. E. B. Marten, their chief engineer, had referred to it in his last annual report as having been caused mainly by changes of form, owing to unequal expansion, in conjunction with a rigid system of suspension. Although this evil was coming now to be generally recognized, no one seemed disposed to take precautions to obviate it, except in one or two cases, where altogether novel types of boilers were adopted; and in one or two others, where it was sought to strengthen

*Abstract of a paper read before the Members of the Iron and Steel Institute, by JEREMIAH HEAD, of Middlesbrough. From the "London Mining Journal."

the boiler by making the bottom plates of Low Moor iron. But at most of the new ironworks, long plain cylindrical boilers were still being placed upon more than two rigid supports. The author then proceeded to explain a model showing the method of suspension and various other appliances he advocated. The boiler represented was 80 feet long, by 4 feet 6 inches diameter, upon five supports. The second and fourth of these were rigid, giving the boiler a constant average height relatively to the brickwork, while the first, third, and fifth, were yielding. This was effected by substituting levers and balance weights for simple suspension rods. Each pair of levers supported one-fifth of the weight of the boiler, whatever form it might assume. In the model, the boiler was actually divided into five sections, jointed together. Along the bottom in a groove was a steel rod 3-16 in. in diameter; one end of this was screwed, and worked in a nut in the fifth section; and near the other end was a collar, working between two guides, secured to the first section. The rod passed also through guides attached to each of the other sections, and upon its front extremity was keyed a small hand wheel. By turning the latter to the right or to the left the action of varying heat in the bottom of a boiler was exactly imitated. The ends or the middle of the boiler were lifted, as the case might be, followed by a corresponding action of the levers and balance weights. The simple manner in which this motion was permitted, without affecting the steam and feed pipe connections, was very remarkable. The author now prefers balance weights to volute springs, for several reasons, not the least of which is, that the former constitute of themselves a perfect pyrometer, indicating at a glance the relative expansion or contraction of the bottom of the boiler, and consequently the inten ity of the heat below. The exploded boiler had been for some months replaced by another upon the previous type, but the bottom plates whereof were of Low Moor iron. The whole range of 15 were illustrated by a large diagram showing also the exact condition, as regards equality of support afforded by the several suspension rods, in which the author found them in a recent visit. Mr. Hawman, manager to Messrs. Lloyd & Co., had assisted and accompanied him in his observation. The boilers are in charge of an experienced foreman, Mr. Wandlass, who, in the author's opinion, bestows unusual care and watchfulness upon the management of them. With regard to the material and workmanship made use of in the construction of the boilers, the author said he was aware he was on tender ground, for his own firm had made the plates, and the well-known firm of Hopkins, Gilks & Co. constructed the boilers. Without either asserting or denying that the casualty was in any degree due to defects of material or construction, the writer did not hesitate to declare that Mr. Gjers, who at that time ably fulfilled the position of engineer to Messrs. Lloyd & Co., took at least ordinary care in getting well-made boilers, and good material, and that the firms referred to exercised at least ordinary vigilance in carrying out their contracts. Unfortunately, ordinary care on the part of employers did not always succeed in securing good work from employes, and, as they all knew, some uncertainty clings to iron products even when manufacturers have done their very best. He did not consider any useful purpose would be derived by discussing at length that part of the subject. Low Moor plates, at £20 to £30 per ton, were undoubtedly better than Cleveland-made ones at £9 5s. Drilling rivet holes was undoubtedly better than punching, and perhaps drifting them, but more costly. The point to which their attention could be directed with real utility, was, *not* whether boiler work could not be made to stand greater strains by employing more costly materials and increased care in manufacture, but whether boiler work, such as it is, and for the most part is likely to be, could not be relieved from some of the great strains to which it was commonly subjected, and, as he thought, unduly and unnecessarily. Referring to the diagram, the writer then called attention to the varying strains upon the several suspension rods. In some boilers the nuts were almost all tight; in one the weight was overhanging from the fourth bearer, throwing the bottom into a state of compression where the flame was hottest. In some the whole weight of the boiler and the water within was, for the moment, carried upon four bearers, in some three, in some two, and in one (No. 7) on the first bearer and on the nozzle at the other end, being a clear span of nearly 60 feet; one boiler (No. 8), which was off empty, was also resting alone on the first bearer and the nozzle, while in the centre it was arched up half an inch clear of its

support; another (No. 9) which was off but full of water, was resting on the first and last bearers, and 3-16ths in. clear of support at the middle. All were under steam except the last two. It was customary in the Cleveland district never to adjust the suspension nuts after a boiler had been once set to work; some, however, adjusted when the boiler was hot, and others when cool. The first method would keep the bottom always in a state of tension, which might become extreme when, in cooling, the boiler endeavored to lift up itself, and perhaps, the brickwork in contact with it; the second method would cause the bottom to be alternately in compression and in tension; it was difficult to decide which practice was the least, or, rather the most objectionable. Mr. Wandlass preferred the first method, but said is was no easy matter to carry it out, for the slightest variation in the intensity of the flame, made some nuts too tight and others too slack. In fact he found it impossible to keep them all bearing equally at all times. The evils described are all greatly aggravated if, when laid off, boilers are allowed to cool too rapidly. Messrs. Lloyd & Co., allow 48 hours before a man can enter. With age a boiler increases its tendency to rise in the middle in cooling, indicating a permanent and gradually increasing contraction of the bottom plates. The author then referred to various details of boiler construction, he condemned hemispherical ends and especially nozzles, while he advocated dished and flanged ends made from a single plate. He also recommended strongly the use of a semi-cylindrical internal tank, for the harmless accumulation and periodic removal of whatever mud might enter with the feed water. He then went into a calculation of the strains to which the plates at the bottom of a boiler as unfavorably supported must be subjected as in No. 7 the strain from steam pressure was only one ton per square inch. That from the weight of the water and the boiler itself, he calculated to be about 4 tons per square inch, in addition, while there were other strains which could not be estimated. By adopting yielding supports the 4-ton strain and some others could certainly be removed. Since the previous portion of his paper had been written, another of Messrs. Lloyd & Co.'s boilers (viz. No. 13), had failed by a seam rip across the bottom, and situated about 2 feet 6 inches forward of the bearer. It went with "a snap" while cooling down and when the water had partly run out. By reference to the diagram, it was evident that at the author's first visit, this boiler was resting mainly on the end bearers. On cooling it would have endeavored to lift its centre portion, and perhaps the brickwork still more, and to rip a seam proved the smaller task of the two. In conclusion the writer disclaimed having selected Messrs. Lloyd & Co.'s boilers as bad specimens. He considered them good ones, and that if they were unsafe, there were hundreds of others which were much more so. Seam rips had occurred at various works, to boilers by various makers, and constructed of various brands of iron. He knew cases himself where Mon-Moor, Dowling, and Low Moor plates had similarly failed. Before taking his seat he would like to say that his object was not to prove that his remedy was the only one possible, for Mr. E. B. Marten had also one of great merit, but he wished to call renewed attention to a serious evil, which he believed could be and ought to be removed forthwith.

PROGRESS OF THE IRON AND STEEL INDUSTRIES.

Abstract of the report of DAVID FORBES, F. R. S., etc., to the Iron and Steel Institute.

From Journal of the "Iron and Steel Institute."

AFRICA.—In consequence of the continuance of the civil war in Spain, and the interruption thereby caused in the mining operations and exportation of iron ores from the district of Bilbao, still more attention than hitherto is now directed to the exploration of the deposits of rich iron ore which are met with so abundantly on the Mediterranean coast of Africa, and large quantities of these ores are now exported not only to France as before, but also to this country, Belgium, Germany, and even to the United States. In the first ten months of 1873, France imported 232,805 tons of iron ore from Algeria.

From New York, it is announced that about 20,000 tons of iron ore have, during the course of the last summer, been im-

ported direct from Bona, in Algeria, one-half for the Bethlehem Works, and the remainder for the Trenton Steel Works. It cost about 48s. when delivered in New York, and was guaranteed to assay sixty per cent. metallic iron along with about six per cent. of manganese; this ore was intended to be used for the production of Bessemer pig iron.

The total production of iron ore in Algeria, in 1872, is given at 334,924 tons, and the total quantity exported to all countries during the interval from 1862 to 1870, at about 800,000 tons; from one mine alone, 55,000 tons of ore was exported to England in the first eleven months of 1872.

M. de Marigny, late director of the Geological College of Algeria, has recently reported upon some large deposits of iron ore which crop out on the right bank of a small river called the Oued-el-Keddache, and are situated at an elevation of about 830 feet above the sea level; about two miles from the port "Aux Poules," and on the line of the projected railway from Algiers to Bongie and Delhys, which passes through the concession of some 2,000 acres in area, held from the government direct upon the usual royalty on all ore extracted. The lode is seen to follow the right bank of the river for some sixty yards, where it is from 36 to 60 feet in width; judging from the numerous large detached blocks of ore strewed on the surface for a great distance it would appear probable that this deposit is a very large one. The ore was found to contain 65·9 per cent. metallic iron, and to be free from both sulphur and phosphorus.

A paragraph has been going the round of the newspapers to the effect that there have recently been discovered, close to the Hills of Moses, near the Red Sea, the remains of immense ironworks, supposed to be at least three thousand years old, and which must have given employment to thousands of workmen. Near the remains are still to be seen the ruins of a temple, and of barracks for the soldiers who have been employed in protecting or keeping the workmen in order.

Australia.—Valuable deposits of iron ore, with seams of coal and fire-clay, are reported as having been discovered in the Strzelecki Range, Gipp's Land, in the property of the Great Victorian Gold Mining Company. At Ballarat, eight veins of iron-stone, which contain from 50 to 60 per cent. of metallic iron, and are said to be from 30 to 40 feet in thickness, have been met with on the western slope of the Moorabool river, in Victoria; deposits of fire-clay and lignite occur in the neighborhood, and the country is covered with timber, which could be used for making charcoal.

Austria.—The great event of the year in this country was naturally the international exhibition, of which, however, so many and so detailed descriptions have already been given in other periodicals, that it is not considered necessary in the present report to make more than a passing reference, and to remark that such exhibits in connection with the iron and steel industries, as were particularly noticed, will be described under the heads of the various countries from which they proceeded. Although, as regards iron and steel, the Austrian and Hungarian works were well represented, there did not appear to be anything specially interesting for its novelty among the exhibits. From the Suedbahn Eisengesellschaft's Works, at Graz, in Styria, excellent steel rails manufactured by both the Siemens-Martin and the Bessemer processes were exhibited, as well as iron rails puddled in the Danks' rotary furnace; among other exhibits were, iron and steel from Kamatow; iron castings from Archduke Albrecht's works, at Teschen; steel and castings from Janowitz, in Moravia; and irons from Siebenburgen and Hungary; good specimens of cast iron railway wheels were sent from Count Andrassy's Dornac Iron Works, in Upper Hungary, and also by Messrs. Ganz & Co., in Pesth; and from the Reichenauer Iron Company's mines and furnaces at Edlach and Reichenau, near the Semmering, on the Styrian frontier, fine cast iron shells were exhibited, one of which, nine inches in diameter, had perforated an eleven inch armor plate without other signs of injury than some three or four minute cracks at the commencement of the ogival part.

Specimens of iron dephosphorized by Jacobi's process, which some time back was described in these reports, were exhibited by the Kladno Iron Works.

Belgium.—Since the publication of our last report, the continental meeting of the Iron and Steel Institute has been held, in August, in Liége, with such pronounced success, that the event may literally be regarded as the inauguration of a new era in the history of the iron and steel industries of Europe. This meeting, besides

being an announcement to the world of the cosmopolitan character of the Iron and Steel Institute itself, as well as the first occasion upon which the representatives of the British manufacturers could come into personal contact with those of Belgium and many other parts of Europe, who had come to Liége for the meeting, has, by its brilliant success, also proved that the time has arrived when it is at last acknowledged that the interests of the individual manufacturer in all countries is most intimately connected with the scientific and practical development of the industries themselves as a whole, and that to shut himself up within the walls of his works, isolated from the rest of the world, is infinitely less to his advantage than to trust to his own merits and enter boldly into the list of friendly rivalry with his competitors. That this spirit animated the ironmasters and engineers of Belgium, when they invited the members of the Iron and Steel Institute to hold their annual meeting in Liége, with a view to a mutual interchange of ideas relating to these industries, was thoroughly demonstrated on the occasion of the August meeting, and the numerous excursions made to the surrounding metallurgical and mining establishments, which, in the most liberal manner, were thrown open to the inspection of the members. It was, indeed, a happy thought which suggested that Belgium should be the first country to welcome the Iron and Steel Institute to the continent of Europe, since this country, apart from the political and commercial relations which have long allied it to Great Britain, was in the fortunate position of a neutral ground during the disastrous war which so lately raged on the Continent. We must refer elsewhere for an account of the meeting itself, with its pleasant excursions, brilliant fêtes, and the lavish hospitality with which the city of Liége, the great establishments in its vicinity, and even His Majesty the King, at Brussels, entertained the members of the Institute, but we cannot refrain from alluding to the unmistakable cordiality of a reception which above all made the members of the Institute carry home with them to England the most pleasing souvenirs of their Belgian friends and hosts.

As an iron producing country, Belgium now ranks fourth in Europe, and fifth in the world; Great Britain taking the lead, followed at an immense distance by the United States of America, and then by Germany or France, the last country having probably lost its position since the annexation of Alsace and Lorraine to Germany; Belgium follows close on their heels, and, with the exception of the above-mentioned, still has a production of more than double that of any other country in the world. The extraordinary rapidity with which the Belgian Iron manufacture has developed itself of late years, is well seen in the case of the Charleroi basin, which, in 1842, produced 40,000 tons of pig iron; in 1852, 81,821 tons; in 1862, 199,790 tons, and in 1872, attained the large amount of 400,000 tons,—thus, in other words, increased 218 per cent. in the first decade, 499 per cent. in the second decade, and no less than 1,000 per cent. in its third decade. Nor did the manufacture of wrought iron remain in arrear of the cast iron production, as, while in 1842 it was only represented by 20,000 tons, it became, in 1852, 37,326 tons; in 1862, 112,290 tons, and in 1872, about 250,000 tons, which figures show an increase in production of 177 per cent. on the first decade, 534 per cent. on the second, and as much as 1,190 per cent. on the third decade.

The state of the Belgian iron trade during the last half-year, 1873, has been extremely unsatisfactory, notwithstanding that the production both of the blast furnaces and rolling mills has been greatly restricted; up to date there appears but little hope of improvement. The steel trade, however, has not suffered in nearly the same degree, and the production of steel is, on the whole, being increased; it is reported that the Société de Sclessin, have applied one of their blast furnaces to the production of Bessemer pig iron.

From the Bulletin de l'Union des Charbonnages, &c., de la Province de Liége, we learn that the Belgium iron trade, taking into consideration its increased proportions, has of late become more and more dependent upon Luxembourg and other countries for its supply of ores; the reason assigned for which is, that the mining laws of Belgium do not favor the development of its minerals.

Brazil.—Immense deposits of magnetic iron ore of the richest class are reported to have been discovered in the Province of St. Paul, at a distance of only some 8,250 metres from the river Jacripiranga, at a point where flat-bottomed steamers can ascend to. Limestone of a bituminous

character, supposed to be indicative of coal, is found in the vicinity, and the whole of the country is covered with virgin forests. An imperial decree concedes these mines to Don Joachim Ignacio Silveira da Motta, and grants permission to found a colony and occupy the land at an extremely low price.

BURMAH.—From the report of Captain G. A. Strover, political agent, Mandalay, on the mineral resources of Upper Burmah, published by order of the Government of India, we learn that iron ores occur in abundance in the Shan States, especially in the district of Pagan, south of Mandalay, where it is smelted in a rude manner and on a small scale at Pohpah Toung. Westwards of Sagaing, for miles up the Irrawaddy river, rich hematite iron ore is found in great quantity, and the Burmese government are now awaiting the necessary machinery and materials from England, for erecting works at Sagaing, for smelting the hematite, it being expected that the surface ore will fully supply these works for years in advance, without mining being resorted to. Limestone is found in abundance, and coal is known to occur in several parts of the Shan States, especially at Meimbaloung, where the deposit has been inspected by a mining engineer and reported to be equal to the best English coal in quality, and to pertain to the true carboniferous formation.

It is proposed to erect new iron and steel works on the right bank of the river Irrawaddy, about twelve miles below Mandalay; these will contain two blast furnaces, forge and rolling mill, and steel works for making crucible cast steel.

CANADA.—It is announced that a company has recently been formed for the purchase of the Haycock iron mines, near Toronto. It is in contemplation to erect blast furnaces and Bessemer converters for making steel, Mr. Holley's estimate of making Bessemer steel being £8 per ton.

A proposition has just been made to the inhabitants of Ottawa, to erect steel works there, which will employ 400 workmen, and require a capital of £100,000; the town of Ottawa being asked to find the ground with buildings, worth together about £30,000.

The recent report of Mr. Richardson, the Dominion Geological Surveyor in Vancouver's Island, shows that there is an apparently inexhaustible supply of iron ore in that district, especially on Texada Island, where enormous deposits of the richest and purest iron ores are stated to occur. As excellent limestone occurs in abundance in their immediate vicinity, and extensive beds of bituminous coal are close at hand, there would appear to be every element at hand required for the successful establishment of the iron manufacture in this colony.

CHINA.—Some information on the state of the iron manufacture in this country may be gleaned from the inspection of a series of specimens of the ores and manufactured products contained in the Chinese department of the Vienna Exhibition, exhibited by M. Prosper Giquel, the manager of the Imperial arsenal at Fu-tschew, in the province of Fu-Kian, in the south of China, who at the same time has afforded some information as to the mode of manufacture carried on in that province. The ore itself is magnetic oxide of iron in small grains, which are disseminated through the sand arising from the disintegration of the granitic rocks, which occur on the eastern slope of the Tajueling range of mountains, and are carried down by river action to the lower parts of the country, where they are washed in troughs by the natives until the lighter particles are carried away and there remains dark-colored sand, consisting chiefly of magnetic oxide of iron, in quantity amounting to about from 1½ to 2 per cent. of the weight of the original sand. This sand is then smelted with charcoal in small tapering blast furnaces, made of refractory clay and bound together by iron rings, the blast being produced by wooden bellows worked by men, and the furnace fed with equal weights of iron ore and charcoal. The product obtained is a mass of crude iron, containing fragments of slag and charcoal, 500 lbs. of the iron sand only yielding about 150 lbs. of reduced iron, which, after being again treated in the same furnace with about half its weight of charcoal, becomes a bloom of more or less steely iron, weighing about 83 pounds. While still hot this bloom is hammered down into bars of about one inch square, which, when cut across into lengths of six inches each, are ready for the market, and are sold to the arsenal at Fu-tschew, at a price of about £11 per metrical ton (2,205 lbs. English). As the bloom of 83 lbs. only corresponds to about 17 per cent. of the weight of the iron sand em-

ployed in the first instance, it is evident that there must be an enormous loss of iron in this process, since the iron sand itself cannot be estimated as containing less than between 50 and 60 per cent. of metallic iron. It appears, however, that the Chinese Government, following the example of that of Burmah, are about introducing important reforms in the iron metallurgy of the Celestial Empire, as they have had a mandarin engaged this last summer in studying the iron manufacture in the United States of America.

FRANCE.—If we are to judge from the speech made in November, at Lyons, by M. Desseillgny, the Minister of Commerce, after his recent tour among the French iron-works of the southern and central districts, there seems to prevail a very high opinion as to their future capabilities, the Minister declaring that they were then in a position to compete successfully with England, and that this favorable state of things ought to encourage them in their efforts to conquer a predominating position in all the markets of the world. He considered the main element to be improved means of communication, especially by inland navigation, and, referring to the Loire iron mining district, which last year had turned out four millions of tons, considered that this might and would be doubled.

The official returns for the first ten months of this year show that 637,956 tons of iron ore was imported during this period, of which 99,590 tons were from the Belgian frontier, 163,519 tons from Spain, 232,805 tons from Algeria, and 111,686 tons from Italy; the whole quantity shows an increase of some 66,000 tons, or about eleven and a-half per cent. over the corresponding period in 1872, which increase is entirely due to the larger importations of ores intended for the manufacture of steel. The imports of metals amount to 108,938 tons of pig iron, 41,109 tons wrought iron, and 5,500 tons of steel; the total imports of pig iron show a diminution of 1,213 tons, or about one per cent., as compared with the same period in 1872, while the quantity of wrought iron was also less by 1,808 tons, or nearly four and a-half per cent. The total exports amounted to 208,693 tons, of which quantity 126,431 tons are the direct ordinary exports, the remaining 82,262 tons being sent out under the special decree which admits pig iron, &c., duty free for manufacture and subsequent re-exportation. The exports, under the above-mentioned decree, show an increase on those of the corresponding period of last year of more than 9,000 tons, or about eleven per cent., while the ordinary exports, on the contrary, are 6,970 tons, or 5-3 per cent. less. From the above figures it would appear that the exportation of French iron has remained about the same as during the previous year, but that less foreign iron has been imported in the same period of the current year.

The steel manufacture in France has gone on steadily progressing, and but little affected by the slackness in the iron trade, as is shown by the quantity of ores suited for steel making now imported, and which, in the first six months of this year, was no less than 40 per cent. more than in the corresponding period of 1872. A company with a capital of two millions of francs was formed, in September, in Paris, for manufacturing steel by Gallet's process.

The Western of France Railway Company, which, up to the close of 1872, had laid down steel rails for more than 146 miles, are extending their employment still further.

GERMANY.—The technical journals of this country, although usually so rich in data for forming a sketch of the progress made in the iron and steel manufacture of the Empire, have during the past months been quite the reverse. In the Berg-und Huetten-Mænnische Zeitung, for the 12th September, will be found a paper on the iron mines of Upper Silesia, and their system of working, by B. Turley, which, however, does not possess any features of interest for the English ironmaster.

From a description of the celebrated steel works of M. Krupp, at Essen, we extract the following particulars:—These works, which at the commencement of this year covered a continuous area of about 1,000 acres, of which 200 acres are under roofing, along with the mines, give employment to about 17,000 workmen, exclusive of 739 foremen and employes, who are in part lodged in 2,948 houses, besides 266 dwellings for the employes, and two hospitals, one with 100, and the other, for infectious diseases, with 120 beds. A body of 166 watchmen, and a permanent fire-brigade of 70 men, who also perform police duty, are employed. The commissariat department has under it—one hotel, three beer-houses, one seltzer water manufactory, a flour mill and a bakery, containing two

steam engines, besides extensive general supply stores, where all connected with the works can purchase, for cash, provisions, clothing, dry goods, &c., at cost prices. There are also a chemical laboratory, photographic, lithographic, and bookbinding establishments, as well as a printing-office, which employs two steam and four hand-presses. A sick, burial, and pension fund has been instituted, to which M. Krupp contributes half as much as the workmen; the annual receipts of this fund amounted in 1872 to £16,000—another fund provides medical treatment to its members on payment of three shillings per head annually.

The number of mines belonging to the works is 414, covering an area of some 50,000 acres, besides which, mines in the North of Spain have been recently acquired, from which an annual supply of some 300,000 tons of ore, suitable for steel making, are expected, as soon as the railway, nearly eight miles in length, now in course of construction (as well as several steamers) is completed.

One hundred and forty coke ovens are in work, and 120 additional in course of construction, these supply eleven blast furnaces with fuel, which turn out nearly 10,000 tons of pig iron per month.

In 1872, the works consumed 500,000 tons of coal, 125,000 tons of coke, and 113 million cubic feet of water, while the gas works on the premises supplied 155 million cubic feet of gas through 16,500 burners.

To facilitate the traffic in the works, there are about 24 miles of usual gauge railway track, with 180 sidings and 39 turntables, which are worked by 12 tank locomotives with 16 inch cylinders and 530 wagons. Ten miles of narrow 2 feet 6 inches gauge track, with 147 sidings and 65 turn-tables, are also worked by three locomotives with 6 inch cylinders and 270 cars; and in addition 191 horses are employed, Communication between the various parts of the works is maintained by thirty telegraph stations.

The works themselves contain 250 smelting furnaces of various descriptions, 390 annealing do., 161 re-heating do., 115 welding and puddling furnaces, 14 cupolas, and 160 furnaces of other kinds, besides 275 coke ovens, 264 smith's forges, and 240 steam boilers.

In the workshops are to be seen 286 steam engines, 71 steam hammers, 362 lathes, 82 shaping machines, 195 boring do., 107 planing do., 42 punching and grooving do., 32 pressing do., 63 grinding do., 31 glazing and polishing do., and 142 other miscellaneous machines.

The quantity of cast steel made in these works in 1872 exceeded 125,000 tons, in the shape of axles, tires, railway wheels, crossings, rails and springs, shafts, artillery shot and shell, boiler plates, &c., the qualities of which are too well known to require any comment, and many of which were well represented at the Vienna Exhibition, particularly in the case of artillery.

Drawings and description of a pair of powerful blowing engines, made by Messrs. Galloway for these works, will be found in *The Engineer* for November 21, 1873. These steel works were lately insured against fire in some twelve German offices for the sum of 6,513,306 Prussian thalers, or not much less than one million sterling.

It is reported that M. Krupp has made known that any workman or employe at the steel works who may take part in the discussion of the religious questions now causing so much trouble in Germany will be immediately dismissed.

GREECE.—It is a considerable time since we have been able to communicate any information as to the iron mines or metallurgy of this country; it appears, however, from the recent number of the *Levant Herald*, that the Hellenic Mining Company has contracted for the exportation to England of large quantities of rich iron ore from its mines in the Island of Seriphos; it is also stated that the large works erected by Tubine, near Newcastle, under the name of the Royal Creek Iron works, for smelting these ores, have commenced operations.

INDIA.—As giving a very good summary of what is known about the modern attempts at iron making in British India, we have been induced to reproduce the following remarks from the *Times* of September 8th, 1873:—"Iron producing minerals are widely scattered over India. There are magnetic and special iron ores and red hematite in beds and veins; there are clay iron ores from the coal-bearing strata; and there are surface deposits derived from the waste of metamorphic and sedimentary strata, and from laterite. The latter formation contains from 20 to

30 per cent. of iron. Some of the most remarkable deposits of magnetic iron ores are in the Salem district of the Madras Presidency. The ores occur in immense beds, 50 to 100 feet thick, and the outcrop may be traced for miles. On one hill, six miles from Salem, there are five bands of magnetic iron from 20ft. to 50ft. thick. At Lohara, in the Chanda district of the Central Provinces, there is a hill two miles long, and a half a mile broad, the surface of which is covered with masses of almost pure iron ore. In Bandalkhand and in the Narbada valley there are large quantities of hematite ores; the supply in many cases is practically inexhaustible. The clay iron ores in Raniganj and other Damuda coal fields yield 39 per cent. of iron. The Kamaun iron ores form an argillaceous band, containing large quantities of red hematite, the ore bed being 10ft. to 20ft. thick, and extending for a long distance. The surface deposits supply the greater proportion of ores used by native smelters, but much labor is necessary in the collection. Iron has been manufactured in India from time immemorial, and iron weapons are found in the ancient cromlechs and kistvaens, but there never were any large works. The production of iron is the work of poor people of very low caste, scattered over the country. They have small clay furnaces, with charcoal for fuel, and the blast caused by foot or hand bellows. The smelting goes on for eight or ten hours, at the end of which time from 10lb. to 20lb. weight of iron is found at the bottom of the furnace; this is purified by reheating and hammering, and the resulting is generally of excellent quality; but the native manufacture is rapidly decreasing, owing to the difficulty of obtaining charcoal. All attempts by the English to manufacture iron in India have hitherto utterly failed. In 1825 Mr. Health, of the Madras Civil Service, obtained a Government advance, and formed a company to establish iron works at Porto Nova, near Cuddalor; at Polamputi, near Salem; and at Bepur, where the iron was obtained from laterite; but the result was nothing but failure, attributed partly to the distance of the works from the source of supply and to the scarcity of charcoal. In 1857, Mr. Sowerby, and engineer, reported on the iron ores in Kamaun, but repeated attempts to work them ended in financial failure; and a similar attempt by a Calcutta merchant, who started works near Suri, in Birbhum, was also abandoned. The enterprise of the Government in the Narbara Valley promised well, and might have been most successful. Works were erected at Burwai, on the Narbada, under the auspices of Colonel Keatinge; Mr. Mitander, a very able Swedish metallurgist, was induced to take charge of the works, and after many experiments all difficulties were overcome, and the works were ready for the production of iron Suddenly in 1864, the Government, after spending £75,000 on these preliminary expenses, dismissed Mr. Mitander, closed the works, and offered them for sale, without success. They have now, with the ground on which they stand, been made over to Holkar. Iron ore and limestone abound in the neighborhood; large forests, furnishing supplies of charcoal, extending for many miles to the east and northeast; and Mr. Mitander was an excellent manager. No record has even been preserved of his experiments and plans for burning and storing charcoal and for other processes which would have been useful at a future time. This year's *Statement relating to India*, referring to these facts, notices that the Government are now once more anxious to foster the iron manufacturing industry of India. Last year Mr. Bauerman was sent out to report on the subject. The increased price of iron is most favorable to the prospect of the manufacture proving profitable in India. The use of Indian coal for smelting iron has never yet been tried.

ITALY.—From a report on the conditions of the mining industry, in the Island of Sardinia, by M. Sella, the Minister of finance, a translation of which is to be found in the *Revue Universelle des Mines*, vol. 33, we learn that veins of magnetic oxide of iron are abundant in several of the geological formations, but that their positions render cheap transport of the ore to a shipping port out of the question except in the single instance of the mines of Saint Leon, Capoterra, on the Gulf of Cagliari, which were in 1861 purchased by the French company, Petin-Gaudet et Cie, for the sum of 29,000 frants, along with an annual payment of 1,360 francs, and in 1863 obtained the definite concession over

360 hectares, or nearly 900 acres. An analysis of the ore was given in our second report for 1872.

The lode or lodes, for there are two, known respectively under the names of Gaudin and Petit, have the direction of the magnetic meridian, and dip into the Silurian Slates to the westward; their outcrop is situated at a height of 400 metres above the level of the sea. The ore had consequently to be brought down by three different inclined planes following one another, and then by a railway to the shipping place in the bay; by these means some 240 to 300 tons per day could be shipped, but the arrangements were so expensive as to cost the company about one-and-a-half million francs before completion, and when the ore had to be mined out by regular workings underground, it was found that while the extraction of ore at the surface did not cost above two shillings per ton, it soon increased to about four times this amount, and the expense of placing the ore on board ship in the bay of Cagliari, without including the expense of management and general charges, was found to be, according to data obtained from M. Gouin, the manager of the mine as follows:—

Mining and Extraction	9·24	francs	per ton.
Transport by inclined planes	1·47	"	"
Do. by railway to the sea	3·75	"	"
Putting on board	1·90	"	"
Total . . .	16·36	francs.	

Which, in 1869, when the price of the iron ore on board ship at Cagliari was not more than from 9 to 11 francs per ton, according to its quality, was not found to pay, and consequently the workings, which employed some 300 men were abandoned, at least for the time. It is reported that they have since been resumed, although M. Sella does not consider that they can possibly compete as to price with the iron ores from either Elba or Algeria.

New Zealand.—From this colony we learn that a company has at last been formed by Mr. Walduck, in England for the purpose of smelting the Taranaki iron sand which has so long been before the British public. On the authority of the *Manchester Guardian*, of the 4th October, we give the following information:—"A number of British ironmasters have just acquired nearly 20 square miles of property in the Wharekawa district, in the province of Auckland, New Zealand. The property embraces 8,700 acres of coal and iron-stone. The chief seam of coal is found in some parts within a few yards of the surface as thick as 20 feet, and it is computed to be capable of yielding an average thickness of 10 feet throughout the whole 8,700 acres. This represents no less than 126,000,000 tons of good coal.

The ironstone is of the brown hematite class, and contains as high a percentage as 62 of fine iron, and is believed to yield an average of 50 per cent. Four specimens reported upon on Thursday, after analysis by a metallurgical chemist in the Midlands, showed 60, 59, 50½, and 36 per cent. respectively. Calcined, it will be worth in this country—as prices are just at present—30s. per ton. Made into iron upon the estate, the coal and iron-stone, estimated each at 8s. per ton, and the limestone, also found on the estate, at 7s., would enable a ton of hot blast pigs to be produced at £2 13s. per ton, and the quality would be equal to British iron which is now selling at £7. Made into cold blast iron, the cost would be about £2 17s. 6d., and the quality would be equal to the British iron which now realizes £8 per ton.

Russia.—The most recent information with respect to the iron manufacture of this country which we have come across, is contained in the Tableaux Statistiques de l' Industrie des Mines de la Russie, en 1871, published in connection with the Vienna Exhibition of this year, by M. Skaljkowsky; from there it appears that in 1871 the number of iron mines worked was 1,174, which turned out a total of 820,000 tons of ore, while in the same year the productions of the various smelting works amounted to 354,000 tons of pig iron, 30,000 tons castings, 241,500 tons wrought iron, and 7,000 tons of steel.

In the Vienna Exhibition, the iron manufactures of Russia are fairly represented. From the north, on the Gulf of Bothnia, samples of the so-called lake ores, a concretionary hydrated oxide of iron, often with considerable oxide of manganese, dredged up from the fresh water lakes, and of iron made from it, are exhibited from Tushby, Uliaborg, and Gamlekarlby; the district between Lake Ladoga and the Gulf of Finland shows white and mottled pig iron with plates, bar and angle iron of good quality, from the ironworks of Warschavsky & Co., at Raivolo, near Viborg, while a collection of the products of his ironworks is shown by Nicolas Poutiloff, of St. Petersburg,

who employs some 4,000 men in the works, or, including those in the mines, carters, charcoal burners, &c., about 18,000 in all. The cannon foundry of Oboukhoff sends a few good specimens of steel guns and mortars, while samples of merchant bar and plate come from the Kamsk forges, on the Viatka river. The great works of Demidoff, at Nijni-Tagil, exhibit pure magnetic iron ores, clay ironstone, and pig iron of excellent quality, while the Rastorgouieff Trustees, from Ekatarinburg, have wrought iron, rough and polished plates and art castings. The Stenbock-Fermor Works, which have seven blast furnaces, supplied with magnetic iron ore from the famous mines of Mount Blagadd, send a model of the works and also bar and sheet iron and samples of the pine charcoal used in its manufacture.

The Imperial Cannon foundry, at Perm, shows a model of one of the largest anvil blocks ever made, as it weighs 622 tons, and is intended for a 50-ton double action steam hammer; some good specimens of steel and steel cannons, and shell, are also to be seen in the arms department, among which was observed an eleven-inch shell, which, after having penetrated an eleven-inch armor plate, has sustained no other injury than having a small piece of the point broken off.

A collection of steel articles, as cutlery, &c., exhibited from Nijni-Novgorod, the Sheffield of Russia, do not come up to the English standard of finish, although probably the material is of excellent quality.

A Russian company has been formed for carrying on the very extensive works of M. Poutiloff, which consist of Bessemer converters, with rail rolling mills near St. Petersburg, puddling furnaces and rolling mill on the Nicolai Railway, and three iron-works in Finland, containing blast furnace, rolling mills, &c. The capital of the company is fixed at five million silver rubles, about £800,000 in shares, along with three million silver rubles, about £475,000, in 6 per cent. debentures.

In England, a limited company, entitled "Tiflis Iron Mines and Works," with a capital of £155,000, in shares of £100 each, was registered in September last, to acquire and work the Bolais Iron Mines and Iron Works, situated about 35 miles from Tiflis, in Asiatic Russia.

SPAIN.—The mineral and metallic statistics of this country are not only extremely behind-hand, but also when they are published are but little to be depended upon for accuracy; the official returns for the year 1870, which are of a very meagre character, have only been recently published by the Government, and will be found in the numbers of *La Mineria* for August 7th and 15th, 1873. From these tables it appears that while the number of concessions of iron mines in force on the 1st of January, 1870, was 582, it had increased to 615 on the 31st December of the same year. During the year 1870, 267 iron mines had been kept in operation by a force of 2,479 men, 162 women, and 152 boys, with two steam engines of a collective force of twelve horse-power, and a total yield of 4,365,861 metrical quintals of iron ore, which, reckoning the metrical quintal at 100 kilogs., will amount to 436,586 metrical tons.

The number of ironworks in operation in 1870 is reported as 75, with a production of 54,007 tons pig iron, and 36,162 tons wrought iron, and employing 3, 570 men, 151 women, and 452 boys, along with 154 water-wheels, representing 1,549 horse-power, and 120 steam engines of 3,796 horse-power.

The above figures show that the production of the year 1870 has exceeded that returned for the preceding year by 125,240 tons of iron ore, 19,521 tons pig iron, and 536 tons wrought iron.

SWEDEN.—In the fourth number of Jern-Kontorets Annaler, for 1873, will be found the particulars of experiments made by Mr. A. Grill, at the Huseby Iron Works, in smelting with a mixture of Swedish coal, uncoked, with charcoal in the blast furnace. The Swedish coal belongs to the cretaceous formation, is, properly speaking, a lignite, and does not coke when heated. The results of the trial smeltings showed, although a very troublesome stiff slag was produced, that the iron was of good quality, and indicated that when a good slag-making flux is employed, the coal could be used in a small proportion with advantage.

The two new charcoal blast furnaces erected by the Central Swedish Iron and Steel Company, Limited, at Bjorneborg, were put in blast in October, on Bessemer pig iron, and are in most satisfactory working; it is expected that the Bessemer works attached to them will be ready early in 1874, when the steel will be run into the converters direct from the blast furnaces.

The Bongbro new Bessemer works' blastt furnaces, and rolling mills, are being rapidly constructed, and will, it is expected, be very soon in partial operation.

At the Startnaes Works, about 47 tons of Bessemer steel ingots are made per week direct from the charcoal blast furnace, which is a small one; this quanity of steel represents between 88 and 89 per cent. of the total iron produced by the blast furnace, and this very satisfactory result is attributed chiefly to the ample power of the two double action blowing cylinders, which are worked by two turbines, each of 175 horse-power; at the commencement and end of the blow a pressure of from 250 to 300 lines of mercury is employed (exceptionally even as much as from 320 to 350 lines), but during the rest of the blow from 120 to 180 lines is found sufficient. By the employment of so high a pressure and quantity of blast, the duration of the operation is lessened and the temperature raised. The converters are lined with quartz, which stands some 60 or 70 blows.

An elaborate series of experiments made on the steel from the Fagersta Works, which fully bear out the good character of their products, has been published in quarto form, with numerous plates, by Mr. David Kirkaldy, entitled "Results of an experimental inquiry into the mechanical properties of Steel of different degrees of hardness, and under various conditions, manufactured by Christian Aspelin, Esq., Westanfors and Fagersta Works, Sweden. By David Kirkaldy. London, 1873."

In the Vienna Exhibition, a large cast iron breech-loading cannon of 24 centimetres calibre, with steel rings shrunk on it, is shown by the Finspong Iron Works, which have so long been known for their excellent cast iron artillery; from this gun 330 rounds had been fired, using 24 to 26 kilogs. of gunpowder, and an iron shot weighing 144 kilogs. Various other guns of smaller dimensions were also shown, and some surprise was expressed at the extremely low prices at which they could be delivered.

United States.—From the statistical report of the Secretary of the American Iron and Steel Association we learn that the production of pig iron in the United States in the year 1872 was 2,830,070 net tons, or 2,526,848 gross tons. This quantity was produced in twenty-one States. The ascertained production during the first six months of 1873 was 1,393,075 net tons, and he estimated production for the whole of the year 1873 is 2,695,434 net tons, or 2,406,637 gross tons. The number of States which made pig iron this year was twenty-two—Maine having re-entered the list after a long rest. The excess of production in 1872 over the estimated production of 1873 is 134,636 net tons. If the financial crisis had not occurred, the production of 1873 would have exceeded 3,000,000 net tons. The estimated annual capacity of all the furnaces in the United States is 4,371,277 net tons.

The total number of furnaces in the United States, exclusive of abandoned and projected furnaces, is 636. The total number of new furnaces finished and put in blast in 1872 was forty-one; finished and put in blast in 1873, forty-two; total number of new furnaces put in blast in the last two years, eighty-three. Many of these are among the largest in the country. By the erection of these eighty-three furnaces, the furnace capacity of the country has been increased fully one-fourth; and what is considered as a pretty close estimate of the entire production of rolled and forged iron, in the United States, for the last two years, is given, in net tons of 2,000 lbs. each, as follows:—

	1872	1873
Merchant bar and rod	500,000	400,000
Sheet and plate	200,000	250,000
Hoop	30,000	30,000
Nails and spikes	175,000	200,000
Axles, etc.	95,000	100,000
Total net tons	1,000,000	980,000
Add iron and steel rails	941,992	850,000
Total rolled iron, net tons	1,941,992	1,830,000

The production of cast steel in the United States is estimated as likely to be about 28,000 tons, or some 4,000 tons less than the quantity returned for 1872; on the other hand it is expected that the production of Bessemer steel will amount to 140,000 tons against 110, 500 tons last year; about 85 per cent. of the Bessemer steel made in the United States is rolled into rails. The total quantity of pig iron converted into Bessemer steel during the first nine months of this year was 127,384 tons, which was more than the quantity converted in the entire year 1872, that being 125,361 tons. The production of steel by the Siemens-Martin process is only a few thousand tons annually, and is confined to seven establishments; one new establishment was inaugurated this year, but it does not appear that steel can be manufactured as cheaply in the States by this system as by the Bessemer process.

The Bessemer steel works at present in operation can turn out annually 170,000 tons of rails, and are situated at Troy, in New York; Johnstown, Harrisburg and Bethlehem, Pennsylvania; Newburg, Ohio; and at Chicago (2) and Joliet, Illinois. When the new plant now being put up at the Pennsylvania Steel Works, at Harrisburg, which will double their present capacity, and the Edgar Thomson Steel Works, near Pittsburgh, are completed, the total capacity of the Bessemer works in the United States may, in 1874, be estimated at about 222,000 tons of steel rails per annum.

For the manufacture of pig iron for conversion into steel by the Bessemer process, it has been found advantageous to import rich iron ores from Algeria by the firms of Cooper, Hewitt and Co. and the Bethlehem Iron Company; for the same purpose a trial cargo of iron ore from Bilbao, containing fifty-three per cent. metallic iron, has also been received by the Pennsylvania Steel Company, and is reported as of excellent quality.

The following figures show a summary, in net tons, of the ascertained and estimated production of iron and steel in the United States in 1872 and 1873:—

	1872.	1873.
Iron and steel rails	941,992	850,000
Other rolled and hammered iron	1,000,000	980,000
Forges and bloomeries	58,000	50,000
Cast steel	32,000	28,000
Bessemer steel	110,500	140,000
Siemens-Martin steel	3,000	3,500
Pig iron	2,830,070	2,695,434

GREAT BRITAIN.—Mr. Robert Hunt, F. G. S., the Keeper of the Mining Records, has lately issued the volume of the Mineral Statistics for 1872. From this it appears that, as far as regards the iron trade, 16,638,599 tons 2 cwts. of iron ore (of which returns were received) were raised in 1872, as compared with 16,859,063 tons 14 cwts. in 1871, and 14,370,654 tons 18 cwts. in 1870.

Pig Iron Manufacture.

The total quantity of iron ore smelted in Great Britain, amounted in 1870 to 14,578,964 tons; in 1871, to 16,859,063 tons; and in 1872, to 16,539,889 tons.

Pig Iron Produced.

	1870. tons.	1871. tons.	1872. tons.
In England	3,735,627	4,379,370	4,594,614
In Wales	1,021,888	1,087,809	1,057,315
In Scotland	1,206,000	1,160,000	1,090,000
	5,963,515	6,627,179	6,741,929

In 1872, the quantity of coal used in the production of this pig iron was:—In England, 11,388,342 tons; in Wales, 2,607,887 tons; and in Scotland, 3,215,500 tons; or a total of 17,211,729 tons. Coke had been computed as coal.

The average number of furnaces in blast in England during 1872 was 449¾; in Wales, 122¼; and in Scotland, 130; total, 702.

The following is a summary of puddling furnaces in operation in the years 1870, 1871 and 1872:—

COUNTIES.	1870. No. of Puddling Furnaces.	1871. No. of Puddling Furnaces.	1872. No. of Puddling Furnaces
Northumberland	54	44	54
Cumberland	95	89	86
Durham	951	1,053	1,135
Yorkshire (Cleveland district)	542	529	492
Yorkshire (Leeds and Bradford district)	247	236	282
Yorkshire (Sheffield and Rotherham district)	353	342	363
Derbyshire	94	91	108
Somersetshire	19	19	19
South Staffordshire	2,037	1,934	2,155
North do.	429	406	446
Shropshire	218	206	184
Lancashire	154	192	178
NORTH WALES	54	54	66
SOUTH WALES—			
Glamorganshire	613	568	594
Brecknockshire	86	62	20
Monmouthshire	553	535	637
SCOTLAND	339	339	486
Total	6,841	6,699	7,311

The number of rolling mills to which the furnaces in 1872 worked was 1,015.

Coal Production of the United Kingdom.

The statistics relating to the production of coal, during the year 1872, will be of interest. Mr. Hunt furnishes the figures which were returned to the inspectors in the various districts at the close of that year. In 1870, he shows that 110,431,192 tons were raised; in 1871, 117,352,028 tons; and, in 1872, 123,497,316 tons.

ON THE STEAM BOILER EXPLOSION AT THE KEYSTONE MILLS.

By W. BARNET LE VAN.

Written for Van Nostrand's Magazine.

On Friday, May 8th, 1874, shortly after three o'clock, a boiler exploded at the above mill, which is occupied by a number of small manufactories. The power is furnished from six plain cylindrical boilers thirty-six inches in diameter and thirty feet long, located on the outside of the mill. The boilers are set in the usual way, two

in each set, three sets; three sets in all, each set fitted with all the appliances required by law. The two sets adjoining the mill having proved sufficient to drive the mill until within a few days prior to the explosion. Owing to a lot of bad coal it was found necessary to fire up the third set which had been standing idle for some time back; one of the boilers was repaired in January last so as to be in readiness in case it was needed. It having been examined by the inspector of a prominent Boiler Insurance Company, under whose charge it was; and the repairs being ordered to be done prior to its being put into service again.

On the afternoon of the explosion the engineer noticed a leak in the repaired boiler, it being the outside one of the third set; he immediately banked his fire, shut off the connections from the other two sets, and was in the act of attaching a pipe to blow them off when the explosion took place.

The boiler parted at the junction of the second and third rim. The front end, consisting of the front head and two rims, was hurled a distance of 150 feet eastward, passing through a shed and landing near the gas-works wall. The back head, with about twenty-five feet of the shell, was shot westward through a coal pile and across a cart-way into another coal pile which was heaped against the wall of the American Soap Company's works, 100 feet distant, the resistance of the coal arresting its flight.

The engineer, Hugh Sweeney, was badly scalded, besides receiving other injuries, and a boy named Thomas Ivan Devor, aged thirteen years, who was employed in the mill, was thrown a distance of sixty feet—both died the following day.

In the coal-yard where the last named piece of boiler landed, and at the time of the explosion, a carter was trying to back a pair of mules attached to a coal-wagon, to a point on a line of the flight of a portion of the boiler, but they were displaying their well-known trait by refusing to back, which fortunately saved them as well as the carter, from instant death.

From a careful examination of the exploded boiler, there is no doubt that it exploded because it was *broken*—"worn out"—it having been in use over twenty years. The average duration of boiler-life is *ten years*.

At the point of fracture, which is in thickness No. 5 or .22 inch, it having been originally No. 4 or .238 inches, it was cut in twain part way through the line of rivets and part way on the line of caulking, no doubt due to a fracture of long standing, from the fact that in two places there was no juncture of the metal, and the circle of the two parts was not distorted in the least by the rupture. This last circumstance satisfied me that a fracture had been in existence for a long time, and that the placing of the new piece on the boiler at this point (the rent passing through the line of rivets which held the new piece to the old rim) and of the same thickness (.238) as it was originally made, was the true cause of the disaster, the old iron having, by long continued use, passed its *elastic limit*, and perhaps beyond it, and the new piece being fresh in its elasticity tended to force apart the fracture and start the rent then in existence.

I would ask the Institute to use its influence with the City Council to have the present Inspection law so changed that there be a limit in the time of the use of boilers.

During the last twelve months there have been thirteen lives lost, beside a large number maimed for life by boilers over twenty years old.

My experience, based on the general usage of boilers of all kinds and conditions, satisfies me that ten years is the average duration of a steam boiler.

EUROPEAN RAILWAYS—AS THEY APPEAR TO AN AMERICAN ENGINEER.

BY W. HOWARD WHITE, C. E.

Transactions of the American Society of Civil Engineers.

A railway built upon the Amsrican idea of first getting the line built on a cheap system, and then bringing it up to first-class rank as the receipts permit, is a thing almost unknown in Europe. In but one case, the writer noticed a road being built upon the economical plan, with wooden bridges.

One thing that strikes an American curiously is the immense amount of trou b

taken by engineers in laying out work for contractors. The immense number of all sorts of signals, grade posts and profiles, the latter not only for banks and cuts, but even for borrow-pits, would render nearly double the number of engineers necessary with which an American road is built.

In making banks, it is the practice to remove the surface of the ground, in case it is either of bad material, or where it furnishes sod for covering slopes, which are almost always either sodded or carefully planted with grass seed, producing undoubtedly a great saving in the after expense of cleaning ditches in cuts. Upon one road in the Tyrol, a curiously favorable combination of circumstances was seen in a low bank across a meadow, formed from side borrows. The sod from the base of the bank was just sufficient to sod the slopes, and at the bottom of the side borrows was found a nice layer of clean gravel for ballast.

Tunneling has been carried to a point in parts of Germany—notably in the Brenner Pass in Tyrol, and on a new road in the Black Forest—the equal of which would be hard, if not impossible, to find in other countries. In one place on the latter line, the engineer having run his grade into the bottom of the valley he was climbing, boldly turned somewhat more than a quarter circle directly into the hill—instead of crossing the valley—and came out again on the same side of the valley, above his previous line. At another place he made a curve of somewhat 90° underground, and then reversed for 30° before coming out again into daylight. The plan of this Black Forest line is a curiosity of itself. It presents two complete S's, in the necessity the engineer was under to get the distance for a certain grade, and there are 25 tunnels in a distance of less than 17 miles, ranging from mere bridge arches in point of length, up to the summit tunnel, which is over a mile long.

Tunnels are made in many cases, where, with us, they would be decided extravagances; but the circumstances are so different—what with the greater cost of the land, and the less cost of labor—that it is impossible as a mere looker-on to judge them. European roads use a greater depth of ballast than is common with us, though perhaps no more, except in rare cases, than is usual on our first-class roads, 18 inches being about the average. The profile of the ballast is generally level or nearly so for the whole width of the road-bed, the entire reliance for drainage being upon the porosity of the material used. German roads, including those of Austria (of which the practice is in the main the same) ballast up to the top of the tie; the English, half-way up the web of the rail, leaving at every third or fourth tie a cross-gutter between the ties; while the French ballast up to the bottom of the top rail-table, rounding the ballast on the inside of the track, however, so as to carry it down to the bottom of the splices at the rails, while remaining of the full height at the centre. The latter practice deadens the noise considerably, but is of course very inconvenient for "surfacing" track.

One is struck even in Germany, where railways are built in a more economical manner than in France or England, with the extravagance, as it seems to us, in certain ways, such as the use of skew bridges, for instance. In a short length of road, over an insignificant stream, one will see two or three skew bridges, where the stream could easily have been turned, to the avoidance of the extra expense. Another favorite and useless feature are the double-deck stone bridges to be seen in various parts of Europe, notably on the road over the Lemmering Pass, not far from Vienna. The engineers of these bridges seem to have been afraid of having the piers shaken down by the motion of the train, and have consequently built their bridges in two tiers of arches, the lower tier serving the imaginary object of preventing a flexure of the piers in the axis of the bridge, and having the disadvantage of detracting very much from lightness and grace.

The favorite iron bridge in Europe, even at the present day, is the lattice truss, with larger or smaller lozenges between the pieces. Wrought-iron is used almost exclusively—except for arched bridges—both top and bottom chords being built up of thicknesses of plate, with a double web at the bottom and top of the upper and lower chords respectively, between the plates of which the ends of the lattice are inserted, and thus secured by riveting to the chords.

The rail sections used on the continent are similar in the main to our own, but much heavier as a rule, and also higher in proportion to the width of the bottom flange, the modern German standard rail section

weighing from 75 to 85 pounds per yard, and being from 4¾ to 5¼ inches in height, with a base of about 4 inches, which weights and proportions are also about those of the most approved French practice. English rails are of about the same weight or a little heavier, but they are almost universally of the double-headed pattern. France has still a number of lines laid with double-headed rails, but the practice inclines to the other. The ties upon the continent are about 3 feet apart. Our practice of placing the ties nearer together equalizes somewhat the lighter weight of our rails.

European rails are generally symmetrical, the inclination for the coning of the wheel being given upon the tie; but in two cases of roads in Germany where new rails were being laid, the writer observed rails going down with the inclination in the head itself, which is, perhaps, an indication of the modern tendency. The more ordinary position on the continent for the notch to receive the spike holding the rail in position longitudinally is the middle of the rail, but since it has been so thoroughly proved that these notches diminish the strength of the rail to a great degree, it is hardly probable that this practice will continue in spite of its convenience as compared with notches at the end.

The split switch so commonly used upon our western roads is almost the only one used in Europe. The switch lever has no locking apparatus, but is kept in place by a counterweight upon a short movable arm nearly at right angles to the lever. The swinging of this arm a half circle around the lever brings the weight into place to hold the switch in one or the other position. This arrangement has the advantage of flexibility, so that the "running through" of a switch by a careless engine-driver does not throw any severe strain upon the apparatus. It would perhaps be hardly safe to apply it, except where, as almost universally in Europe, the switchman is constantly on hand to see that everything is right.

The gauges throughout Europe are, with few exceptions, 4 feet 8½ inches. The most notable are of Spain and Russia, the former being 5 feet 8½ inches, and the latter, 5 feet.

In Germany, the first item in the way of signals that strikes an American is the electric bell system used for communicating information or instructions of simple character to the watchmen who are stationed at more or less regular intervals—generally at level crossings—along the line. Each watchman's station is provided with a gong of large size, mounted upon a little building—or rather, upright box, containing the mechanism. The gongs, by the way, are generally double, and the notes are made harmonic, being said to be more effective for hearing than single bells. Upon all of these bells between any two stations, signals are made simultaneously by means of hammers striking the bells, operated from either terminal station. The signals given are few in number, the chief ones being the departure of a train from one or the other station, signaled by a different number of strokes. The effect of the striking of these bells is sometimes very pretty, particularly when heard from a high point, where those at several stations can be heard striking at the same time, the strokes coming to the ear, however, at different instants.

Many roads upon the continent now use an electric switch signal at either end of a station ground. This signal stands normally at danger. When, however, a train is expected and everything is clear, the switchman sets the signal at "all right," whereupon an electric bell is set in motion at the station, which rings until the train has passed, and the watchman has released the signal, which goes back to "danger." It will be noticed what a safe signal this is. Since it stands ordinarily at "danger" no train can enter the ground until the signal is set. If either the signal is not set, or the apparatus has fallen out of order, the station-master, not hearing the bell in action when the train is expected, investigates the matter. If, on the contrary, the signal does not go to "danger" after the train has passed, or if the apparatus gets out of order, so that the bell continues to sound, the station-master is equally warned. This apparatus is used upon a few roads with us, the Eastern R. R. of Massachusetts for one since the unfortunate collision at Revere, some years ago.

A little convenience for superintending engineers, road-masters, and others interested in knowing the rate of grade at different points of the line is to be found in the grade posts set throughout Europe, at the points of change, consisting simply of a post, rising any convenient height above ground (most commonly only a foot or two), with two pieces of board fastened to it like

the arms of a sign-post, which are, however, inclined to show the direction of the respective grades, and are marked with the rates of grade, and generally with the lengths of the respective inclines or levels.

Signals and crossing-gates, the latter generally being simply bars like old fashioned well sweeps, held open by a counterpoise on the short end, are operated at long distances, in some cases (at different ends of a tunnel for instance) as great as a mile or more, by wires running upon little rollers at regular intervals; a system which I believe is only to be seen upon our side of the water, upon Canadian roads, unless in some exceptional cases.

Traversing and turn-tables for transferring freight cars from one track to another are very much used; every station being provided with at least one transverse line of rails for connecting the various tracks. The transverse track on the same level with the main lines, and having turn-tables at its intersections with them, is the most popular, and is a decided convenience where a large staff of employés is on hand to move cars, but the much greater length of our cars, and the consequent increase in the expense of such apparatus will probably prevent its being adopted extensively in the United States.

There is one use of traversing tables, however, which has not fallen under the writer's observation in the United States, and which seems a very useful one in cases where economy of space in engine-houses is a consideration; that is, what is called the rectangular system. As practiced in France, where chiefly used, it consists in arranging the engine stalls upon parallel tracks in a building divided in the centre by a pit, with a transverse system of rails, carrying a transfer-table. Each of the parallel tracks gives two stalls, lying upon either side of the transfer pit, whose table, generally provided with a small steam-engine, gives the means of moving an engine from the entrance track to any stall, and vice versa. Under the system as practiced abroad, the pit is covered, which involves a great expense of roof over waste space—the chief defect of the system. If snow should not prove too great an obstacle, there would not seem to be much reason otherwise why the pit should not be left open, dividing the house into two separate ones. The system offers considerable advantages over lunettes or round-houses for repair engine-houses, in the greater facility it affords for setting up shafting or traveling cranes.

The lightness of the running gear of European rolling-stock strikes the American observer. Freight cars weighing but 10,000 pounds, carry 20,000 or even as much as 30,000 pounds; and although the proportion is generally far from being so favorable in the passenger stock, it is on an average, perhaps, even more favorable in comparison with our own. Some of the double-deck cars, which are quite common upon French roads, exhibit a most extraordinarily small proportion of dead weight. One on exhibition at Vienna, with a capacity of 90 persons, weighed only 11.75 tons. It would seem these cars might be made even lighter, were it not for the side buffing system, which throws heavy diagonal strains upon the floor frames. The secret of the thing must lie in the superior average character of European permanent way, and it is an interesting question, if, upon the gre t roads with us whose road-bed and tracks are nearly or quite as good as those of Europe, it is not possible to make some radical reforms in that matter, at least in passenger stock, which is not liable to wander upon badly kept roads.

The wheel-coning in Europe is generally $\frac{1}{20}$, the tendency being rather towards increase than diminution, some roads having made it as high as $\frac{1}{18}$, and $\frac{1}{17}$ having been found to give good results. The Vienna & Salzburg line tried the experiment of doing it away altogether, but it is conceded that the results are bad.

Brakes in Europe are seldom applied to more than a limited number of vehicles in a train. The French "Direction of Roads and Bridges" has declared the Westinghouse brake too complicated in its connection between cars to render its adoption probable upon French roads; a dictum rather astonishing to any one who knows how infinitely more simple the connection is than the ordinary European car-coupling, which involves the giving of at least half a dozen turns to a sort of vice-handle which has to be released and seized again at each turn.

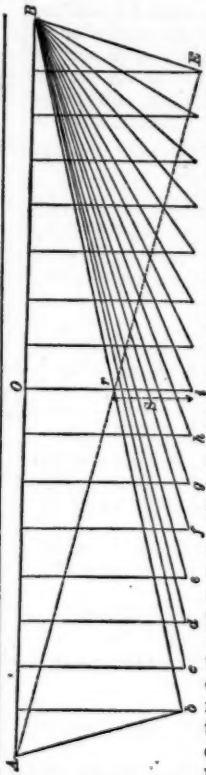
AN ERRONEOUS BRIDGE FORMULA.

Written for Van Nostrand's Magazine, by Ernst A. Harris, C. E.

In the January number of this magazine of this year, there appeared an article from F. W. Smith, pointing out discrepancies between two methods of calculating the stresses upon the main chord of a Bollman truss. In this article it was shown that a formula "given by Shreve Molesworth and others," gave the stress on the chord in a certain numerical example as 320 tons, while the method used by Trautwine, Vose, etc., gave the stress as 425 tons, making a very important difference. The article in question was headed "An Open Question in Bridge Building," and though it successfully pointed out the discrepancy above and indirectly inferred that the formula $\frac{W L}{8 D}$ in this case = 320 tons, was erroneous, it did not show where, and appeared to leave the question partially undecided; speaking as if the error was due to the use of the method of moments round a point. The subject of this article is to decide the point in question, by showing that the formula $\frac{W L}{8 D}$ is entirely erroneous; that the erroneous result obtained is not due to the use of the method of moments, but to a wrong assumption in the use of the method; that the method, when correctly applied, gives the same result as the other methods; secondly to examine another form of the Bollman truss, not touched upon by F. W. Smith, and for which an erroneous formula is also given.

To do this, it is only necessary to introduce the following axiomatic formula, from the eminent works of Prof. Macquorn Rankine.

Theorem,—"If a frame be acted upon by any system of external forces, and if that frame be conceived to be completely divided into two parts by an ideal surface, the stresses along the bars, which are intersected by that surface, balance the external forces which act on each of the two parts of the frame."



Only one system of diagonals is shown, those from each end cross $o\,i$ in exactly the same point in pairs.

To apply this theorem to the Bollman truss in the example in question, let W = total gross load; let L = span; let $\frac{W}{L} = w = w\,t$ per unit of length; let D = depth of the truss; let H = thrust along the chord A B. Let the distance at which any diagonal rod crosses the upright $o\,i$ from i be designated by s. Thus for A E, $r\,i = s$. Let the tension on any one of the rods, as L B, resolved into its horizontal component = t.

Take a section through the middle of the truss. The moment of the external forces acting on each of the two parts of the bridge about the section $o\,i$ is then given by the well-known formula of half the intensity of the load into the product of the segment of the line A B which reduces to $M = \frac{W L}{8}$ = moment at $o\,i$. Shreve now proceeds to place this = H D, because, says he, "Taking moments round the point (i) in the centre of the truss and in the line of the lower ends of the vertical braces, the strains in the inclined braces crossing the centre may be disregarded, as their amounts in opposite directions exactly balance each other, and we have therefore $H D = \frac{W L}{8}$."

Here is where the mistake is made; instead of the stresses on these braces crossing the centre, balancing each other about the point i, they being tension all act in the same direction around the point i.

The horizontal component of the stress on each rod is t, as there are two rods at each point, their moment around i will be $2 \Sigma t s$, where Σ denotes the sum of their moments. So that we shall have for the moment exerted by the bars at the section $o\,i$ H D $-2 \Sigma t s$, which must equal the moment of the external forces $\therefore$ H D $- 2 \Sigma t s = \frac{W L}{8}$. Hence for the example given by Shreve, where W = 240 tons, S = 160 ft., D = 15′, and taking the stresses along the diagonal rods as calculated by himself, we have the following table, by multiplying the stresses along each rod by the cor. of the angle it makes with $o\,i$.

Dis. from i or s for		Stress along	Horizont. Comp. of Stress.	Moment about i or $2\,t\,s$.
i B	0	40.71	40.00	0.0
h B	$\frac{1}{4}$	39.92	39.375	131.25
g B	3	37.92	37.50	225.00
f B	$4\frac{1}{4}$	34.69	34.375	281.25
e B	5	30.23	30.00	300.00
d B	$7\frac{1}{2}$	24.54	24.40	281.25
c B	$\frac{20}{14}$	17.60	17.50	787.50
b B	7	9.42	9.38	131.25

Total or $= \Sigma\, 2\, t\, s = 1{,}575.00$,

which, substituted in the equation

$$HD - 2\Sigma ts = \frac{WL}{8}, \text{ or } \frac{WL}{8} - HD + 2\Sigma ts = o$$

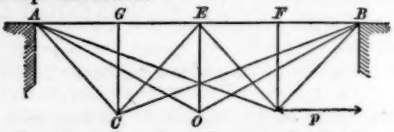
gives

$$\frac{240 \times 1^{6}0}{8} - H \times 15 + 1575 = o,$$

whence H = 425 tons, which shows that, if no wrong assumption is made, the method of moments brings out the correct result.

Another proof of this is given thus; by the theorem stated by Rankine. The horizontal stresses of the bars to the right of $o\,i$ must balance the external forces acting on the left or H $\pm \Sigma 2\, t\, s = o$, and if $\Sigma\ 2\, t\, s = o$ as Shreve assumed, then H $= o$, or there would be no stress along A B at all, a dilemma which cannot be escaped so long as it is held that the stresses along the inclined rods crossing the middle balance each other.

There remains another variety of the Bollman truss to be considered, which is given by Nystrom in his "Pocket-book of Mechanics and Engineering," edition 1872, page 303, of which the following figure is a representative.



Let L = span, W gross load; D = height of bridge; p = length of panel. H = thrust.

For this Nystrom gives the same formula

H or greatest thrust $= \frac{L\,W}{8\,D}$

The following consideration will demonstrate the erroneousness of this formula.

In the first place, let us use again the axiomatic theorem stated by Rankine and take a section to the right of E O, and indefinitely near it. Then for equilibrium round o the sum of the moments of all the forces acting round that point must be zero. The bending moment is as before $\frac{L\,W}{8}$. The moment of H round o is H D, and the moments of the stresses on the rods around o will be as before $\Sigma t\ s$, so that we have, as before, $\frac{L\,W}{8} - H\,D + \Sigma t s = o \therefore H = \frac{L\,W}{8\,D} + \Sigma t\ s$.

This will give the same value to H as in the other variety of the truss, which is thus proved.

A certain portion of the weight at C goes to B, by means of C E; call this $\frac{W}{a}$. Its horizontal component $= \frac{W}{a}$ ten GCE $= \frac{W}{a}\,\frac{p}{D}$. Its moment about $o = \frac{W}{a}\,\frac{PD}{D} = \frac{W}{a}\,p$

Now let us suppose that this weight $\frac{W}{a}$ goes over C B instead of C E. Its horizontal component $= \frac{W}{a}\,\frac{3\,p}{D}$ and its moment about $o = \frac{W}{a}\,\frac{3p}{D}\,\frac{D}{3} = \frac{W}{a}\,p$, so that the value of $\Sigma t\ s$ is not altered whichever way the weight goes, and therefore the value of H is the same as if all the weight at C went by way of C B 2 E D.

The same thing might be shown by the resolution of forces, thus H or comp. of $\frac{W}{a}$ over C E $= \frac{W}{a}\,\frac{p}{D}$ horizontal comp. $\frac{W}{a}$ along O B $= \frac{W}{a}\,\frac{2p}{D}$. Sum $= \frac{W}{a}\,\frac{p}{D}$

$+\frac{W}{a}\frac{2p}{D}=\frac{3}{a}\frac{W}{D}\frac{p}{}$ but this is the horizontal component of $\frac{W}{a}$ over C B.

It is evident, therefore, that a dangerous mistake is made, by using the formula which is the subject of this article.

[Note by the editor. That the horizontal stress in the chord of a Bollman truss depends upon the number of panels, and that the value of this stress lies between $\frac{W\,L}{8\,D}$ and $\frac{W\,L}{6\,D}$ may be shown in the following manner: Employing the notation of this article, and using n for the number of panels,)whence $\frac{L}{n}$ = length of one panel), we have

$\frac{W}{n}$ load at b

$\frac{W}{n}\times\frac{n-1}{n}$ = portion of this load conveyed to A.

$\frac{W}{n}\times\frac{n-1}{n}\times\frac{L}{n\,D}$ = horizontal stress arising from this load.

$\frac{WL\times(n-1)}{n^2D}$ = ditto.

The load at c is the same in amount, but $\frac{Wn}{n}\times\frac{n-2}{n}$ = portion of load conveyed to A, and

$\frac{W}{n}\times\frac{n-2}{n}\times\frac{2\,L}{n\,D}$ = horizontal stress arising therefrom.

$\frac{WL}{n^2D}\times\frac{2(n-2)}{}$ = ditto.

The sum of all these forces is evidently

$\frac{W\,L}{n^2\,D}\left((n-1)+2(n-2)+3(n-3)+\cdots n(n-n)\right)$

which reduces readily to

$\frac{W\,L}{n^2D}\times\frac{n^2-n}{6}=\frac{W\,L}{6\,D}\left(1-\frac{1}{n^2}\right)$ the total horizontal stress on the chord.

When $n=2$, the smallest admissible number, then the thrust is $\frac{W\,L}{8\,D}$.

When $n=\infty$ the thrust becomes $\frac{WL}{6\,D}$]

REPORTS OF ENGINEERS' SOCIETIES.

THE AMERICAN MASTER MECHANICS' ASSOCIATION.—The seventh annual session of this Association was held in Kingsbury Hall, Chicago, beginning on May 12th, and the three days following.

The President, Mr. H. M. Britton, in his very able address respecting railroads and the grangers, observed:—Involved in the question of operating the rolling stock, for which you are directly responsible, is the cost of moving large bulks great distances, and selling them at a profit. All the injury to the railroad interest of the country which a misconception of this great question could do, has been worked within a year. It is hardly possible to overestimate that injury. It had its origin in something akin to fraud, perpetrated by those who projected and constructed railroads, on the people of neighborhoods through which they passed. To obtain from the farmer pecuniary aid in way of donations, by representing to him that his bulky freight, in the shape of farm products, would find a high market, and a low rate of freight, was one unfailing financial resource of the projectors of these unnecessary roads. It was the hope held to the view of the honest and unsuspecting husbandman, built upon a foundation of misrepresentation and falsehood. It has borne the bitter fruit which might have been foreseen. The deceived farmer, finding the rate charged by the railroad did not bring him the promised market for his products, became a granger, the granger became a legislator, and treated the railroad interests of great States with arbitrary laws and enactments. To regulate trade, not by the law of supply and demand, not by the cost of doing the business, but by legislative enactment; to say that a railroad shall haul a ton of freight for one-half a cent when the absolute cost of hauling is one cent a ton, is as if you should require the farmer to sell his corn at twenty-five cents a bushel when he can realise fifty cents by feeding it to hogs; or, as if you should legislate him into a sale of his hogs at some particular place in the State at half their market value. This seems absurd enough; nevertheless, the granger, deceived into donating his money to build the railroad, legislates with the passion of resentment, not with the wisdom which follows calm reflection. In Wisconsin, the railroads complain that this legislation amounts to a confiscation of the railroad property. What doubt, what distrust, what absolute ruin overhangs a great commercial interest, thus threatened by hostile legislation!

The committee on the operation and management of locomotive boilers presented a very long report. The report discussed:—1. Incrustation; its causes, effects and cures. 2. The deposit of sediment; its effects and remedy. 3. The impurities in water which produce priming; its effects and only remedy. The committee reached the following conclusions:—That owing to the fact that no panacea could be found for all the incrustation diseases, it is evident that if it is to be cured by remedies at all, a diagnosis of each case must suggest the proper treatment.

The committee on the best form of safety-valve, or methods of relieving boiler overpressure, and the best way of testing pressure gauges, presented a report, in which the expression of opinion in regard to direct spring valves was, with few exceptions, in their favor. The grounds for this preference were stated to be their compactness and simplicity, the quick relief which they afford to an excess of pressure, their prompt closing when the pressure falls, and the fact that they are or may be made independent of the control of the engineer.

The report of the committee on a mechanical laboratory embodied in elaborate detail the following apparatus:—Adjustable model of valve motion; machine to test tensile, torsional, and com-

pressive strength of metals; machine to test friction of metals; machine to test lubricating value of oils, &c.; steam-engine indicator, with full diagram apparatus; most approved speed or revolution counter; pyrometer for testing high boiler temperature; thermometer with long range; vacuum gauge for use in locomotive smoke-boxes; mercurial column for testing steam-gauges; registering dynamometer for obtaining train resistances; microscope for the examination of metals; means of testing calorific value of different classes of coal, and principle of their most economical combustion; means of testing various qualities of water; means of testing acids in tallow under high temperature; means of testing incrustation compounds, and discovering their injurious ingredients when any; means of testing composition of specimens of boiler scales, &c.

The committee appointed to prepare subjects for discussion at the next meeting prese ted the following:—The best material, construction, operation and management of locomotive boilers; purification of feed-water—what methods up to this time have been most approved for the improvement of feed-water by chemical and mechanical means, and for the prevention of incrustation; locomotive tests—this committee to request members to make experimental tests to show the performance of locomotives, and to report the results to this association; locomotive construction—this committee to report as far as possible all new methods of construction which have been adopted by members during the past and ensuing year; the best system of signals for operating railroad trains, including train head signals, train tail and side signals, road or station switch signals, and appliances for indicating the speed of trains; locomotive and tender wheels—this committee to report breakages of wheels and tires, removals of tires, and causes of breakage or removal, and to report on the different methods of construction and manufacturing of various kinds of engine and tender wheels; construction and improvement of continuous train breaks during the ensuing year, and their application to cars and locomotives; lubricants for locomotives; mechanical laboratory; finance; trustees of Boston fund; printing; general supervisory.

The Committee on Valves and Valve Gear presented a long report. Fourteen members responded to the circular sent out by the committee, from which the following conclusions are deduced:—Of the fourteen members answering to the circular, four report in favor of balanced valves, and six against, while nearly all agree that there is a reduction in wear o seats and gear and increased ease in handling. The grounds of objection are liability to blowing and difficulty of keeping in repair. The mileage of the balanced valve, where comparisons have been instituted, is considerably in its favor, as against the flat valve. Seven replies are in favor of decreasing the size of parts from their experience, and two offer simply an opinion against reduction.

The Committee on Tires having presented its report, say:—The superiority of steel tires having been already demonstrated, all that remains to be determined is, which is the best tire, and how thin steel tires can be worn with safety. As it will take time for the steel tires now in use to wear out, we are not likely to obtain the desired information in regard to either of those points for some time to come. The whole number of sets reported on is 359. Upon the subject of setting and fastening steel tires, of the fifteen companies reported, ten use shrinkage alone, two use shrinkage and set-screws, and three use set-screws alone. The amount of shrinkage allowed is:—Five allow 1·100 inch to 1 foot in diameter of wheel; one allows 1-32 inch to a 5-foot wheel and less in proportion: one allows 1-80 inch to 1 foot in diameter of the wheel if soft, and less if it is hard; one allows 1-20 inch to a 5-foot wheel; one allows 1-16 inch to a 5 and 4½-foot wheel he secures by a screw; one allows 82-1000 inch to a 5 and 5½-foot wheel; one uses set-screws 1½ inch in diameter, and allows shrinkage 1-16 inch to 5½-foot wheel, and the same proportion to a 4½-foot wheel; one uses set-screws and allows 1-32 inch shrinkage to a 4½-foot wheel; one uses lap bolt through felloe of wheel, countersunk 3-8 of an inch in the tire. The Great Western of Canada uses set-screws with thread of screw run 7-8 of an inch into the tire, but has no thread cut in that part of the screw which passes through the rim of the wheel. The reports indicate that chilled tires will average about three years in durability; the lowest thickness of tires at removal was 3-16 inches, the average about 1½. Steel driving-axles and truck wheels were generally preferred. The Great Western of Canada prefers axles of good hammered iron.

The Committee on Standard Axles presented their report, in which they recommend the following proportions for freight and passenger car and tender axles:—Total length over all, 6 feet 11½ inches; journal, 3½ inches in diameter, by 7 inches long; wheel 4 7-8 inches in diameter by 8 inches long; diameter in centre, 4 inches; color, 4½ inches in diameter, by 5-8 of an inch thick. The committee are of opinion that owing to the great diversity in the construction of locomotive engines, no standard for the form and proportions could be adopted in the construction of the axles, without first making important modifications in the design and dimensions of other parts of locomotives.

The Committee appointed to report on Oils for Locomotive Use, came to the following conclusions from communications received:—The majority recommend the use of No. 1 extra lard oil, while others insist that it caused rust, and declare that sperm oil is the proper thing. The use of mineral oil is condemned, but plumbago faintly recommended. As to water used, it was thought more lubrication was needed where hard water was the supply.

Mr. Wells, Chairman of the Committee on Continuous Train Brakes, read a report of great length. Replies to their circular had been received from twenty roads. Of these three only use hand-brakes, fourteen the Westinghouse air-brake. The theoretic requirements of a perfect continuous train brake were declared to be as follows:—Certainty of instant application to all or as many of the wheels of the train as practicable; the retarding power should be capable of being graduated at the will of the person applying it, under all ordinary circumstances; when applied from any cause, it should so remain until the train is brought to a stop, unless persons in charge of it desire otherwise, in which case it

should be capable of instant, partial, or total release; the brake power should be under the control of the engineer of the train; it should apply itself in case of derailment of any part of the train, or in case the train should part accidently, and should be capable of application from any car in the train at the will of the person thereon, when necessary.

The Committee on Machinery for supplying Water to Tanks recommended the use of a natural fall to get water into the tank where practicable; windmill, where the formation of the country will permit. Next, steam power.

The election of officers was postponed for one year, allowing the present officers to hold another term. The principal being the president, Mr. H. M. Britton, of Cincinnati, and the secretary, Mr. J. H. Setchel, of Cincinnati.

The Convention adjourned, to meet in New York on the second Tuesday of May next year.

ENGINEERING STRUCTURES.

FIRE-PROOF FLOORING.—As bearing on the subject of so-called fire-proof buildings, now being considered in our columns, we think it will prove of interest to refer to some experiments recently carried out at Erith at the works of Messrs. Easton & Anderson. We have already dwelt upon the fact that wrought iron as commonly employed to resist the action of fire, and even when protected by concrete, has shown itself to be entirely unreliable in fire-proof structures. It is, however, well known that fireclay forms a much more efficient material for protecting wrought iron from the destructive action of intense heat, and it is with the application of this material by Mr. J. Whichcord, the engineer to the National Safe Deposit Company, that such good results were obtained the other day at Erith. The arrangement consists merely in employing a number of fireclay blocks about nine inches long, and from one and a half to two inches thick, formed on one side with recesses of an L form, so as to fit closely to the web and bottom flange of the wrought-iron girder. The outer sides of the blocks can be made of any desired form to receive ceiling arches or joists. The blocks being placed upon the girders, meet underneath the bottom flange, and the longitudinal as well as the transverse joints are made good with fireclay. Returning to the experiments at Erith. A furnace fifteen feet long and four feet wide in the clear was constructed, and across the top a rolled iron joist of I section, seventeen feet long, ten inches deep, and with five inch flanges, was laid spanning the length of the furnace. This girder was protected with blocks in the manner above described, and on each side of the girder, brick arches were built abutting against the side walls of the furnace. Over the top of the arches and girders a thickness of concrete was laid, and the floor thus formed was loaded with pig iron, to one-fourth of its breaking weight. After the structure was thoroughly dried, a fierce wood fire was made up in the furnace, and was maintained for two and a half hours, when large quantities of water was thrown on the heated mass. The deflection of the loaded girder had when heated amounted to one and a quarter inches, but when the weights were removed, and the beam had cooled, the deflection disappeared, and it remained apparently uninjured, although the fireclay sheathing was vitrified on the surface.

A second experiment was made on the 28th ult., when a fierce fire wa kept up for one and half hours, and then maintained moderately for twenty-eight hours more, after which it was suddenly extinguished with cold water. The deflection of the loaded girder had been 3-32 in. at the commencement of the trial and reached a maximum during the fire of 1 3-16 in., reduced to 3-8 in. when the load was removed, but before the beam was cold. Ultimately, however, it returned to the original amount of 3-32 in.

Altogether this experiment, which was carefully carried out, shows the enormous resisting power of the fireclay blocks, and it may be mentioned that one end of the girder which projected through the brick work of the furnace was quite cool, when the fire was at its hottest, and no appreciable expansion was observed. The beam will be employed in the building for which it was originally intended.

OPENING OF THE ST. LOUIS BRIDGE.—CHARACTER AND DIMENSIONS OF THE STRUCTURE.

ST. LOUIS, Mo., July 4, 1874.

The formal opening of the Illinois and St. Louis Bridge was celebrated to-day with great enthusiasm. Th display was finer than ever before witnessed here. The procession was five hours in passing a given point. Addresses were made by Mayor Brow, ex-Senator Gratz Brown, Governor Woodson, of Missouri, . d Governor Beveridge, of Illinois.

DESCRIPTION OF THE BRIDGE.

The completed bridge is of three spans of 497, 515 and 497 feet respectively in the clear, each span formed with four ribbed arches of cast steel. The double rib enables the arch to preserve its shape under all circumstances of unequal pressure on its parts and obviate the necessity of a spandrel bracing. The spans rest on piers of granite and concrete, built on the bed rock of the river. The upper roadway is fifty feet wide between the railings, two foot-walks, each of eight feet, and a road-way of thirty-four feet, occupyi g the space. Below the carriageway are the railway passages, each thirteen and a half feet in the clear and sixteen feet high, extending through arch openings of the same size in the piers and abutments. On the other side of the river five stone arches, twenty feet wide, carry the railways over the levee and wharves; they are enclosed by a cut stone arcade of twenty arches, supporting the upper roadway. Brick arches conduct the railways into the tunnel at Third street and along this, upon a six foot bed of macadamized stone, the trains will run to the Union depot. The carriageway runs on a level to Third street. On the Illinois side the carriage road descends at once with a grade of five feet in 100, while the railway tracts curve off north and south over the approaches of trestle work, with a descending grade of one in 100, till at a distance of 3,000 feet they reach the level of the Illinois roads. At its lowest point, in accordance with the requirements of the federal law, the bridge is fifty feet above high water mark. From the roadway it is at present between ninety and 100 feet from the surface of the river.—*Herald.*

IRON AND STEEL NOTES.

Communication Relative to Converting Pig Iron into Steel by Berard's Process. By M. Aristide Berard, Paris. The author is the inventor of a process for the direct conversion of pig iron into steel by using gases in a reverberatory furnace with movable bottom placed in a peculiar manner. By means of an oxidizing or reducing action, regulated at will by the operator, and acting in the metal bath by the help of dipping tuyeres, the decarburation of the pig iron is moderated with mathematical precision, and the waste reduced to a minimum. The puddling, in a measure mechanical, effected by the blowing in of air and gases bringing constantly together the metal and slag, facilitates the elimination of foreign bodies injurious to the quality of the steel (such as sulphur, phosphorus, &c.), allowing thereby the use of pig iron of an inferior quality in obtaining certain products. By the means adopted for the production of gases as well as for their application, the exceptionally high temperature is developed which is indispensable for the production of certain qualities of steel. The steel obtained from this high temperature, and under the action of hydrogen, without the injurious effects of an oxygenous cementation, has special qualities of resistance, malleability, and welding. Under the aforesaid conditions of manufacture, steel ingots may be obtained easily at the price of iron.—*Journal of Iron and Steel Institute.*

Production of Highly Silicised Pig Iron. Since our last report, in which we gave an account of Professor Jordan's researches on this subject, a paper entitled "Researches on cast irons rich in silicon," has appeared in the Annales des Mines, for 1873, in which the authors give the results of their investigations into the behavior of compound of iron with silicon under various circumstances, showing that the reducing action of the carburet of iron on silica is a very slow one, and that it is interfered with by basic slags, their experiments having proved directly that when a silicious cast iron is melted with lime or with a very basic silicate of lime, silicon is removed from it. They also consider that one of the causes of the formation of cast iron containing much silicon is the presence of alkaline silicates in the furnace, and state that a mixture of carbonate of potash, charcoal, iron filings, and silica, when melted in a blast furnace at a high temperature, will at once afford a cast iron containing as much as from 15 to 16 per cent. of silicon, along with 2.94 per cent. carbon, a result which they consider due to the reduction of potassium, which by re-acting in its turn on the silica, sets the silicon at liberty to combine with the iron.—*Journal of Iron and Steel Institute.*

Influence of Titanium in Iron Smelting.—As it is well known that cast irons made from most ores containing titanic acid, do not themselves contain any, or only a trace of titanium, the precise reason why this substance should have this beneficial influence on the quality of the iron or steel made from such ores, which is generally ascribed to it, is somewhat difficult to explain. In the Jern-Kontorets Annaler, it is stated that it is common in Sweden, when the iron ores are sulphury, to add to the charge titanic iron ores (containing less than 10 per cent. titanium), which, it is asserted, prevent the iron produced becoming red short, possibly, it is imagined, owing to the formation of compound of sulphocyanogen with titanium; as yet, however, there is no evidence to prove that titanium has the same influence on the smelting of ores containing phosphorus.

Action of Slag on Fire-Clay. The results of an experimental inquiry into the behavior of different fire-clays when in contact with iron blast-furnace slag at high temperatures has been published in Dingler's Polytek. Journal, cciii., p. 445–450, by Carl Bischof. The experiments were made by mixing the fire-clays with the desired proportion of powdered slag, and moulding it into a small cylinder which is exposed to the heat until it loses shape. With Hessian fire-clay, 1 per cent. of slag is sufficient when the temperature is as high as the fusing point of platinum. Gruenstadt, Muelheim, and Belgian fire-clays required from 5 to 7 per cent.; Laaren No. 2 fire-clay, 6 per cent.; Garnkirk, 8 per cent.; Laaren No. 1, 13 per cent.; and Zellitz fire-clay, 14 per cent. Of course, these results are merely comparative, since blast-furnace slags vary greatly in chemical composition; and in trials made with two different slags, one produced along with grey Bessemer pig iron which contained 54 per cent. of lime, and the other from white iron, with 41 per cent. of lime; the latter exhibited less tendency to make the fire-clay fusible.—*Iron and Steel Institute.*

RAILWAY NOTES.

Abolition of the Broad Gauge.—During Friday, Saturday and Sunday last, the Great Western Railway Company has converted its south-western lines from the broad to the narrow gauge. The work began at daybreak on Friday morning, and the following account shows the magnitude of the task and the precautions which had to be taken:

For some days previous to commencement of the work, the broad gauge stock was gradually worked off the line, and on Thursday evening each station-master had to give a certificate that his station and district was clear of broad-gauge rolling stock, the last trains of which arrived at the Chippenham end of the line about midnight, and were sent to appointed depots. Immediately afterwards the line was handed over to the engineers, who were entrusted with the supervision of the work between Chippenham and Weymouth, Bathampton and Weymouth, and various branches in connection, the largest of which was that from Witham to Wells. About 2,000 men were engaged on the work, the company having concentrated a number of men on various sections of the work. Each man received 1s 3d. per day for rations, and the company found oatmeal and good water for making a wholesome and strengthening beverage. Sheds were also erected where sleeping accommodation was scanty, and the men worked seventeen or eighteen out of each twenty-four hours, their energy and steadiness being remarkable. The scene along the whole of the line was a most busy one.

The *modus operandi* was as follows:—Only one rail on each line was moved; but for some weeks past the men have been engaged in clearing out the ballast to facilitate the shifting of the wood and ironwork, and also in partially sawing off the

'transoms." Where the rails were laid on "chairs" and "sleepers," additional chairs have been placed, so that the rails had to be simply moved from the old to the new set of sleepers and secured. In cases where the rails were fastened to longitudinal timbers, the partially sawn transoms were completely severed, and the rail and baulk pushed into the proper gauge and fastened. The men wore numbers, and worked in small parties, and the conversion was effected with surprising rapidity. Where double lines existed, as was the case over a material portion of the distance, the work was, of course, doubled. The greatest possible precautions were taken during the few days previous to the commencement of the work in order to prevent accidents. Pilot men wearing badges, and each carrying a written authority, were attached to the engines working on single lines. These officials were responsible for the safe working of the line, and were instructed to tell their drivers to diminish speed at certain points where any supposed weakness existed. The same will be the case on the resumption of traffic.

The narrow gauge is also down between Bath nd Bristol, and will be opened simultaneously.

A Railway up Mount Vesuvius.—The *Liberta* of Rome describes the model of a "funicular railway," the concession of which has been applied for to the Italian Government by a company that proposes to construct it up to the crater of Mount Vesuvius. The model consists of an inclined plane, presenting a gradient of thirty-three per cent., with a double line of rails, one for going up, and the other for the descent. The engine, which is fixed at the bottom of the plane, sets two drums in motion, round which the metallic cable is wound by means of which the trains are drawn up and let down simultaneously. This plan appears to be preferable to the rack-and-wheel system used for the ascent of Mount Righi, both as to the working and cost. The section, to the slope of the mountain at San Guiseppe, is to be performed by common locomotive, the rope is then put on, and the ascent commences by the new plan. The whole length of the railway will be sixteen miles; the time required between Naples and the crater is calculated at an hour and a quarter, and the whole cost of the line is estimated at four millions of francs. The funicular system is of course no new invention—the improvements lie in the details. The company are very sanguine as to the results; they say that as upwards of 40,000 travelers annually ascend the Righi for the sake of its fine view, they may expect more to go up Mount Vesuvius, which owing to the sea, offers a far more magnificent view.

The Bombay, Baroda and Central India Railway Company have been engaged during the past year in preserving the stability of the bridges. Their engineers have been successful in screwing additional piles into the beds of the rivers to a far greater depth than was originally thought necessary, and they hope, therefore, to secure the stability of the piers in the extensive rivers they cross. The sheds for the protection of fuel have recently been considerably extended; they are now completed at five of the principal stations on their line. The Dakore branch, 16½ miles in length, was opened on the 8th of April last for passenger traffic, and for goods traffic on the 20th of that month. The branch has been constructed on the standard gauge of 5½ft., and with rails of 60lb. to the yard; the cost, exclusive of rolling stock, has been only £4,000 per mile, which is thought to be very creditable to the company's engineers. The State line is being extended from Delhi to Ajmere, and it is of great import, ance to the company that the line should be extended from Ahmedabad to Ajmere to complete the communication from Bombay to the Northwest Provinces. The company have proposed to make thaportion of the line on any gauge the Government may deem expedient. The Company's engineert have constructed three tank engines in the works shops at Bombay, and they are much admired for the completeness of their construction. They have also aided the Government in the supply of 500 goods wagons to meet the requirements of the famine.

BOOK NOTICES.

Tri-Nitro-Glycerin as applied in the Hoosac Tunnel. By George M. Mowbray. New York: D. Van Nostrand. Price, $3.00.

Besides the history of experiences at the Hoosac Tunnel, this work of an experienced chemist treats fully of the methods of manufacture and the conditions of proper use of Nitro-Glycerin, and other explosives derived from it.

The author says: "Since the introduction of this explosive as a substitute for gunpowder in the Hoosac Tunnel, accidents from explosion have diminished two-thirds of the previous average rates, progress has advanced from the rate of sixty-one feet per month in September, 1868, under State supervision, to four hundred feet per month in September, 1873, under contract; being six-fold; and in February, 1874, tri-nitro-glycerin delivered at one dollar per pound, possessing an admitted force of ten times that of the best mining powder, is a reduction in cost of explosive force, in favor of nitro-glycerin, of over thirty-three per cent. * * * Add to this that nitro-glycerin will blast out holes four times the depth of powder-charged holes, and the saving of time in removing and replacing the drilling machines is apparent, and its usefulness to the contractor indisputable."

Several full page illustrations embellish the work.

Earthwork Mensuration on the basis of the Prismoidal Formula. By Conway R. Howard, C. E. New York: D. Van Nostrand. Price, $1.50.

It seems to be universally conceded that in earthwork calculations, methods based on the prismoidal formula only should be employed. "Average" and "Mean Average" methods are too inaccurate for even the most simple cases; moreover the percentage of error is so variable for the different commonly recurring conditions that such approximate methods are doubly unsatisfactory.

In employing the Prismoidal Formula three plans of working are open to the computer.

1st. The direct application of the formula to each case; involving the determination of mid-way section in each prismoid. 2d. Employing carefully

prepared tables. 3d. Using the graphic method, or rather charts in which linear intersections point to tabulated results. We confess a strong preference for the second plan. The first plan is of course free from any suspicion of error, but it involves an unnecessary expenditure of time, inasmuch as in successive prismoids with similar slopes and bases, much work is repeated. Well directed efforts to save this loss of time lead directly to the employment of the second plan; and it is a conspicuous merit of the work before us that the method of calculating the tables is so clearly and concisely set forth, that no one capable of using any method safely can fail to understand how to prepare such tables as these, or to extend the set in the book to any desired limit.

The third plan referred to above is employed by many who desire to reduce the use of numbers to a minimum. Trautwine's Tables afford the best known example, and are widely used. For beginners in field work, whether students in scientific schools or engineers of fresh experience, the methods involving the construction and use of tables seem to us far preferable to any others. For such Mr. Howard's book is sufficient.

REPORT ON THE EFFECTS OF THE SEA-WATER AND EXPOSURE UPON THE IRON-PILE SHAFTS OF THE BRANDYWINE-SHOAL LIGHT-HOUSE. By Lieut. Col. JOHN D. KURTZ and Capt. MICAH R BROWN. Washington: GOVERNMENT PRINTING OFFICE.

This report affords minute details of the examination of a system of Iron Piles, seventy-seven in all, which have been exposed to the action of sea-water for periods varying from sixteen to twenty-five years. The measurements made of the diameters of the piles at different levels are carefully tabulated. A valuable addition to the literature of practical engineering.

CANADIAN PACIFIC RAILWAY—REPORT OF PROGRESS ON THE EXPLORATIONS AND SURVEYS. By SANFORD FLEMING, Engineer-in-Chief. Ottawa: MCLEAN, ROGER & Co.

This report will be read with interest by many who feel no concern about the feasibility of the proposed railroad, and as if to satisfy the wants of such, the report is replete with information about the territory surveyed. The maps, which are quite numerous, are drawn upon a large scale, and afford an important addition to the geography of our country.

COAL AS A RESERVOIR OF POWER. By ROBT. HUNT, F. R. S.

ATOMS. By PROF. CLIFFORD, M. A. Boston. ESTES & LAURIAT.

These two essays together form No. 11 of "Half-Hour Recreations in Popular Science."

The first is an elementary exposition of the laws of heat, or rather of the laws governing the generation of heat from combustion.

The second essay is the longer one and by far the more abstruse; the illustrations employed by the author to elucidate the properties of matter when in the gaseous condition seem to us peculiarly apt and forcible. In these Half-Hour Recreations much sound knowledge may be obtained.

ON A NEW METHOD OF OBTAINING THE DIFFERENTIALS OF FUNCTIONS. WITH ESPECIAL REFERENCE TO THE NEWTONIAN CONCEPTION OF RATES OR VELOCITIES. By Prof. J. M. RICE; U. S. Naval Academy, and Prof. W. W. JOHNSON, St. John's College. Cambridge: Welch, Bigelow & Co.

This is a pamphlet of twelve pages only, but presents an introduction to the differential calculus which many learners will prefer to either of the methods usually employed. The writers are evidently both familiar with methods of instruction, and have presented the subject in a form adapted to beginners in the subject; although the work as submitted is for those who have progressed beyond this entrance gate to the higher analysis, and it is evidently designed that instructors may enjoy the benefit of commanding for their pupils another approach to the heights which the majority attain only with difficulty.

The essay deserves wide circulation.

THE ELEMENTS OF ALGEBRA. By F. A. SHOUP. New York: E. J. Hale & Son. Price, $1.50.

The author has compressed the usual course of Algebra as far as Logarithmic Series into small compass without omitting any important topics. The Expositions are very concise and the examples under each topic few in number. The work affords good suggestions to the instructor, and will prove of more use to teachers, we judge, than to learners. The book is in a very neat form and invites by its appearance a close acquaintance.

A MANUAL OF INORGANIC CHEMISTRY. The Iron Metals. By T. E. THORPE F. R. S. E. London and Glasgow, Wm. Collins, Sons & Co. Price, $1.50.

This neat little volume is simply an expansion of the first portion of Elementary Inorganic Chemistry to a little more space than it generally occupies in our School Text-books. The nomenclature is of the new system, of course, and the exposition of the method of establishing the atomic weights is very clearly rendered.

There are no questions nor problems, but this lack may be supplied in the second part, which is to treat of the metals.

SHORT LECTURES ON SANITARY SUBJECTS. By RICHARD J. HALTON, London: Bailliere, Tindall & Cox. For sale by Van Nostrand. Price $2.50.

The subjects of the lectures, twelve in number are: 1st. The Necessity of Sanitary Science. 2d, Air. 3d, The Sick Room. 4th, Ventilation. 5th, The Relation of Popular literature to the Public Health. 6th, Food. 7th, Clothing. 8th, Cleanliness. 9th, Training and Education of the Young. 10th, Epidemics. 11th, The Influence of Amusements on the Public Health. 12th, Overcrowding.

The lectures are of an exceedingly practical character, and emanating as they do from an author who holds many prominent positions in leading institutions, they cannot be regarded as otherwise than very valuable.

THE PRACTICAL ASSAYER. By OLIVER NORTH. London: Chatto & Windus. 1874. For sale by Van Nostrand. Price, $3.75.

This work contains easy methods for the assay

of the principal metals and alloys, and it is principally designed for explorers and those interested in mines. It provides for a want that has long been felt,—a knowledge of practical modes of assaying, without any general or extensive knowledge of analytical chemistry. Assaying is a mere mechanical art, and some of the best and quickest assayers have been mining youths who could hardly write their own names and were not analytic chemists at all. All hard words and formulas have been left out, and only easy and useful methods, which do not need expensive apparatus, have been given, so as to be useful chiefly to the mining explorer.—*Builder.*

"THEORY OF THE STRENGTH OF MATERIALS, illustrated by applications to Machines and Buildings," by Francis L. Vinton, C.M.C.E., Professor of Civil and Mining Engineering, School of Mines, Columbia College. New York. D. Van Nostrand. Price $3.00.

These notes were originally prepared for the course of Machine and Mining Engineering, in the School of Mines, Columbia College. The author has added to these, during the printing of his MSS. such other notes on Civil Engineering, as had then been introduced into the school. Consequently the arrangement of subjects is not altogether as he would have desired, and it is intended in future editions to remedy this defect. No tables have been introduced, because in the view of new experiments now prosecuting at the School of Mines and elsewhere, upon American material, the old tables have become comparatively worthless. The work will be found to be invaluable to engineers and students.

AN INTRODUCTION TO THE SCIENCE OF HEAT. By T. A. Orme. Third Edition. London: Groombridge & Sons, 1874.

This manual is intended for the use of schools and of candidates for university matriculation examinations, and as heat is now placed on an equal footing with dynamics and statics in the matriculation programme of the London University, it will prove specially useful in the preparatory studies of that institution. The use of arithmetic instead of algebraic formulæ throughout the work makes it suitable for the higher classes of schools, and the arithmetical accuracy to which the phenomena have been reduced render the science of heat peculiarly well adapted for study in superior seminaries.

THE GUN, RAM AND TORPEDO. London: J. Griffin & Co. For sale by D. Van Nostrand. Price, $4.25.

It was fortunate for the honor of the British navy that when the Shah inspected the twenty-five ironclads at Spithead, they were safe at anchor; for if any admiral knew how to lead such a fleet of dissimilar ships into action, it is certain that few of the twenty-five captains could have executed the necessary manœuvres. Much credit is due, therefore, to the Junior Naval Professional Association for offering a prize of fifty guineas for the best essay on the tactics of future naval battles. The result is this volume containing three essays treating the subject from three very different points of view. In the almost entire absence of exact data, speculation, opinion and assertion, find far too prominent a place in them, showing how exceedingly defective all naval education and training is in the art of war. "From a general point of view," writes the talented author of the second essay, "the subject has been systematically neglected and discouraged, and the few who have attempted to investigate its rules have been looked on as wild theorists. Opinion in respect to this is now happily changing; it is no longer held to be unprofessional, unseamanlike, un-English, to know anything about the conduct of a fleet, or to have ideas extending beyond holystones or scrubbed hammocks." As a sample of historical study and accurate reasoning, this second essay will probably outlive the first or prize essay; but for the present needs the rough guesses and bold assertions of the latter give it a greater temporary value. If we regard them simply as essays or attempts to solve a problem without data, they will do much good by indicating its difficulties, and by pointing out the necessity of employing our officers and our squadrons in time of peace in efforts to discover the uses in war of their ships, their guns, their rams, and their torpedoes, instead of concentrating their energies on useless fopperies and frivolous labors resulting in nothing higher than spotless decks, polished guns and symmetrical clothes' lines. The naval architect should study this volume if he would thoroughly appreciate the influence of his art on the conduct of fleets, and the primary necessity of quick turning powers in efficient war-ships. It is, indeed, the rapid revolution in naval architecture which has discomfited seamen in tactical knowledge, and makes them so ignorant of the efficient use of their weapons. If this volume lays this ignorance, its chief work will have been done.

MISCELLANEOUS.

MAGNIFICENT PROJECT.

A bold and splendid project, and one the successful accomplishment of which would bring enough of the glory it loves to satisfy even *la grande nation*, has been laid before the Geographical Society of France, and approved by that learned fraternity. It is no less than to add another sea to the oldest continent by admitting the waters of the Mediterranean to a series of the depressions, partially filled with fresh water, in the south of the French colony of Algeria. These lakes, locally named chotts, run dry at certain periods of the year. But a chain of them, the first of which is only separated from the Mediterranean by sandy downs, extends as far as Biskra, to the south of Constantine. The last of the chain being twenty-seven metres below the level of the sea, it is thought feasible, by cutting through the sand above the first chott, to admit the waters of the Mediterranean to this series of lakes, and thus form a salt-water lake at the southern extremity of the chain important enough to admit of the creation of seaports. "From these advanced posts," says the author of the report on this scheme, "we should watch the nomadic tribes of the south. The numerous and

rich oases of the Souf and the Oued, now only nominally subject to us, would fall completely into our power. Our colonization would extend to the south of Constantine as surely as it is established on the Mediterranean coast."

BLASTING IN MINES BY ELECTRICITY.—The inventor of a very useful electric exploder, F. Abegg, engineer at Neu Bistritz, Bohemia, has continued to use almost exclusively, during a term of seven years, the electric current for firing blast holes, and he has at last succeeded in bringing his invention into a perfectly defined shape. Instead of galvanic, Mr. Abegg invariably uses frictional electricity for mines, which he produces with a small machine that is enclosed in a light case, and always ready for use. A very great advantage and saving by the use of electricity in blasting is derived from the possibility of igniting simultaneously a number of charges, when their spheres of active friability will join each other, and thus bring under violent vibration a much larger mass of rock than if the same charges were fired one after the other. These advantages are very conspicuous when driving or sinking in a hard rock. The system of Mr. Abegg is simply as follows. The electric exploder or machine is placed at a safe distance, say five fathoms above or by the side of the bore holes, and connected with a piece of cable which contains two insulated copper wires, the ends of which are b nt into eyes and protected against injury by being wrapped up with tarred hemp, so that only the eyes protrude. Into each is then hooked a piece of annealed iron wire, which should be at least 2.5 millimetres thick, and conducted to the blast hole. This is loaded with the usual charge of powder or dynamite, and at the same time Abegg's ignition rod is inserted. The latter consists of a round, straight rod of dry wood, tightly wrapped in oiled paper, with a groove on each side which contains a piece of conducting wire, ending at the top in an eye, and reaching at the bottom in the detonator or percussion cap, which is fastened to the end of the rod so that the electric current goes through one wire in it and returns by the other. In these eyes the further ends of the iron connecting wires are then hooked when the charge is ready for explosion. Where several holes are to be blasted simultaneously, it is only necessary to connect the two most distant holes with the machine, each by one wire only, and to complete the electric conduit between them by short pieces of wire which are hooked in the nearest eyes of the exploding wires. When the current is turned on it will run from the exploder through the cable and one iron wire to the first hole, pass from one to the other, and return from the last by the other iron connecting wire; and as the velocity of the current is so great that it is practically instantaneous, all detonating caps and blasting charges will explode exactly at the same time. Should the holes be very wet, it is only necessary to cover the igniting rods, besides oiled paper, with a thin layer of pitch, when they will never miss fire.

SAPPHIRES IN COLORADO.—The Denver, Col., *News*, of the 3d inst. says:

A miner who has been engaged some months past working in the bars along the Platte for five or six miles above Denver, had the good fortune to find several sapphires, which he saved, without knowing anything about their value. One day last week a stranger, who was prospecting along the river, was shown the stones, when he bought the largest one for two dollars. He brought it to town, and upon a test, it was pronounced a sapphire, and a very fine one. It was placed in the hands of I. Haberi, lapidary, to be cut. The rough stone weighed 19¼ carats; and yesterday he delivered to the owner a beautifully cut gem therefrom, weighing fully 12 carats, and valued at $500. The miner was also in town yesterday, and became very much astonished upon learning the value of the pebble he had parted with for a two-dollar greenback. He left two more with Mr. Haberi, and proposes to enjoy, himself, some of the profits of their polishing. The gentleman who bought the first mentioned stone is experienced in such things, though a comparative stranger in this region. In the past week he has himself found within two miles of Denver an emerald, which he believes more valuable than the sapphire, and a very fine water agate which will produce a beautiful gem of strawberry color. He has sent the emerald east.

ACCORDING to competent authorities, the sulphur mines of Sicily will be exhausted in fifty or sixty years. There is only about 200 million cwt. to be extracted. The quantity taken out annually at present is about 2½ million cwt.; but allowing for the progress of industry, it may reach 3 or 4 millions. The Italian Government lately appointed M. Lorenzo Parodi to inquire into the present state and the future of this industry, and he has published an interesting report on the subject. The sulphur, it appears, is found in Sicily in two different forms; that of a deposit from volcanic emanations, named *solfatara*, and that of deep beds., in which it is associated with sedimentary rocks, and which are known as *solfaras*. The treatment of the ore is very primitive. It is simple fusion, in which the sulphur itself serves as fuel; and it is done in the open air, without any regard to the waste which results, and which is considerable. Thus the ore, which contains sulphur in the proportion of 15 to 40 per cent., yields generally only two-thirds, or, on the average, 14 per cent. The production of the mines has quadrupled in forty years, spite of the greatly increased consumption of pyrites (in which, it is known, the sulphur is combined with iron), and M. Parodi therefore thinks it inexpedient to abolish the export duties, which bring into the Government 2,000,000fr. per annum, in order to stimulate a production which will of itself go on increasing towards the date of exhaustion.

MR. CHARLES JORDAN, an ironfounder, at Newport, Monmouthshire, has taken out a patent for a novel method of preventing railway accidents. He proposes to make the up and down main lines without the usual switches, turnouts, and crossings, the lines being continuous from end to end, and to work such road by transferring a train or trains at stations, or where shunting is necessary, or at junctions with other railways, from the main line to the adjacent sliding, by lifting the train bodily from one line to the other by hydraulic apparatus.